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COSTS OF URBAN INFRASTRUCTURE FOR INDUSTRY AS RELATED TO CITY SIZE IN DEVELOPING COUNTRIES

India Case Study

Final Report

A Joint Study By:

SRI

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

SPA

SCHOOL OF PLANNING AND ARCHITECTURE

NEW DELHI

SIET

SMALL INDUSTRY EXTENSION TRAINING INSTITUTE

HYDERABAD

COSTS OF URBAN INFRASTRUCTURE FOR INDUSTRY AS RELATED TO CITY SIZE IN DEVELOPING COUNTRIES

India Case Study

Prepared under
Memoranda of Understanding

between

Stanford Research Institute

School of Planning and Architecture

Small Institute Extension Training Institute

under contract with the

Agency for International Development

PREFACE

The aim of this study is to compare the costs of supplying the physical and social infrastructure required by industry in urban centers of different size in developing countries. Possible variations in infrastructure costs in cities of different size are an important consideration in framing policies for the location of industry and for the promotion of industrial growth and employment opportunities outside major metropolises. This study is not an assessment of policies and strategies for decentralized industrial development, but the cost issues analyzed here are fundamental to such policy alternatives.

A related aim of the research is to develop information on the association between types of industries and city size, and on the cost characteristics of specific infrastructure facilities and services, in a form useful to industrial development agencies, investors, city planners, and urban facility managers. Knowledge of these relationships and costs is needed in estimating and evaluating levels of public investment, facility expansion, and site development required in support of new industry in different types and sizes of city. Physical infrastructure includes the following facilities directly supporting industrial production and distribution: electric power, road and rail transport, telephone communications, water supply, and sewage and industrial waste disposal. Basic requirements of housing, schooling, and hospital and health services for urban industrial employees and their families, together with the residential share of refuse disposal, police, and fire protection services, are covered in social infrastructure.

The report is a collaborative effort of SRI (Stanford Research Institute), the SPA (School of Planning and Architecture), and the SIET (Small Industry Extension Training Institute). In obtaining and interpreting field data to find out what such costs and industry patterns actually are, it was necessary to break new ground in defining costs and in developing methods for measuring them. As a point of departure, the current literature on these and related matters from a number of countries was reviewed. The most pertinent works are listed and described in the study's Annotated Bibliography. The attempt has been to develop a methodology that will be applicable in other regions and countries.

In the application of the industrial location factors and cost analyses presented in the report, local conditions are obviously paramount. At various points, the report indicates how local factors might be taken into account and how necessary supplemental data collection and analysis might be built into ongoing operational and study activities which urban and industrial development agencies and research institutes are generally already engaged in for capital budgeting and industrial planning purposes.

Although the present study is essentially a binational venture, the origins of the research are in several countries. Lively, hard questions on the most suitable regional and urban distribution of new industry have been raised with staff members of the SRI International Development Center in most industrializing countries where they have worked. These include Peru, Mexico, Colombia, Bolivia, Ecuador, Argentina, Israel, India, and Pakistan. The same kinds of questions are faced in regional development efforts of such industrialized economies as Canada and the United States. Quickening of staff interest in these issues from such varied geographic angles led to the proposal, by SRI to the Agency for International Development (AID), upon which this project is based.

India's attention to the problem of regional development, originating during the period of the independence movement, has evolved in research projects as well as investment programs during each Five Year Plan. The analysis by the Gokhale Institute of Politics and Economics in the early 1930s of the wider benefits of irrigation projects was in many ways a forerunner of today's use of comprehensive benefit-cost analysis in evaluating regional projects. The Research Programmes Committee of the Planning Commission has sponsored in recent years studies on facets of regional development, including industrial complex analysis, transport surveys, identification of growth centers, and urban industrial studies During the preparatory phases of the present project, meetings of representatives of the Planning Commission, Dr. William Bredo and Richard Morse for SRI, and AID confirmed this as an important subject of mutual research interest. It was agreed that field research should be conducted in India, provided that suitable collaborative plans could be worked out.

Groundwork for collaboration and for the structure of field research was laid in the Preliminary Report prepared by SRI through the leadership of Dr. Carlton L. Wood. The Preliminary Report surveyed the current theoretical and empirical status of the issue of urban centering in regional development, the policies now used in some countries with the aim of promoting satisfactory regional patterns of industrial growth; and the factors in the infrastructure requirements of particular industries and their cost patterns. A supplement outlined the cost characteristics of 15 major physical and social infrastructure facilities. Statements of the proposed research hypothesis and scope were also developed.

After review of the Preliminary Report and related papers by government and academic institutions concerned with this research in India, Carlton Wood and Richard Morse conferred with scholars and administrators of these institutions in July and August 1966. The research experience and initiative of two institutions--the SPA and the SIET--proved to be particularly pointed and complementary toward the research problem.

The SPA with its central purpose of training city planners has directed graduate studies on industrial typologies and interactions among cities, and on localization and specialization of industries. Work by the School's faculty on industrial estates and on industrial structure

and performance standards in different cities underlies the analysis of infrastructure standards and costs that is central to the present study.

SIET is engaged in these issues through managerial and industrial engineering analyses of small and medium manufacturing plants, and industrial development studies in specific districts which it undertakes as the core of its applied training of industrial managers, developers, and extension agents. Faculty members have carried out research on pilot industrial feasibility studies, interfirm comparisons, and identification of growth centers.

It was concluded that a three-way research partnership would be rewarding. The three institutions proceeded to develop and agree upon a plan of research. Completed in December 1966, the Research Plan set forth objectives, scope, hypotheses, and research methodology for the study and established staff requirements, work schedules, and budgets. With concurrence of the Government of India and the United States Agency for International Development, pursuant to a Project Agreement authorizing support to the rupee budgets established in the Research Plan for each institution, SRI entered into Memoranda of Understanding with SPA and with SIET for the purpose of the project. The collaborative agreements became effective in March 1967.

Given the broad character of the research problem, the essence of the Research Plan was to foster professional understanding and teamwork among specialists in the three institutions: urban planners, public work system cost analysts, civil and electrical engineers, industrial economists and industrial management specialists, and regional and urban economists. It was clear that design and execution of the field research required a well integrated approach. The SPA and SIET project leaders, M.C.K. Swamy and Om Prakash Mathur, joined the SRI team at Menlo Park in March and April 1967 to prepare the field Research Design. The Design was reviewed at a two-day meeting of the U.S. Advisory Committee and in individual meetings with members of the India Advisory Committee. Prior to the start of field work in May 1967, SIET faculty members conducted a brief orientation for research staff on objectives and methodology. SPA established project offices for the combined SRI, SPA, and SIET staff and for mapwork, statistical analysis, and administrative support.

The substance of the research is in the team interviews carried out from May through December 1967 with managers, engineers, accountants, and workers in some 208 manufacturing plants and 465 public facilities in 18 cities. Questionnaires serving as the basis for interviews are illustrated in the appendixes. The reality of the fieldwork, however, is but dimly visible on paper. Its vitality was drawn from the zest of project staff in whetting each other's keenness with challenges on

the relevance and "do-ability" of specific steps in the research, in pursuing facts to needed accuracy, and in keeping a constructive skepticism in interpreting data. Vitality and purpose were also built from the examples of vigor and originality demonstrated by numerous industrialists in the cities visited in operating with sparse infrastructure support; from the ingenuity and competence of numerous managers of power, water, transport and other facilities in upgrading the quality of their services; and from the wit and common sense of workers in responding to discussions of the adequacy of housing, schooling, and related public services. Effort, intellectual thirst, and learning might be said to characterize the fieldwork stage, on behalf of all.

The India Advisory Committee met with the project staff in December, 1967, to review plans for the final phase of fieldwork, the industrial and residential site selection and estimation of incremental infrastructure costs in five test cities. With this phase completed, Krishna Swamy and Om Mathur returned to SRI in February, 1968, for analysis of data and preparation of the draft report. This benefited greatly from the help of staff participants and Advisory Committee members. Principal findings and conclusions were orally presented at a conference with AID in Washington in June. Revision of the draft report in response to major suggestions was undertaken immediately and completed by mail after return of the SPA and SIET project leaders to India in June.

Our acknowledgments are due to many people who have contributed to the project. Of particular importance has been the personal interest and support given from the inception of collaborative discussions and throughout the project by Professor T. J. Manickam, Director of the SPA, and Shri P. D. Malgavkar, Principal Director, SIET. The active interest and counsel of Dr. John P. Lewis, Minister-Director of AID, New Delhi, and Stephen Bergen, project liaison representative for AID, Washington, has been of major assistance.

The constructive, specific criticism of members of the Advisory Committees has been especially welcome. Clarifications and insights provided by our staff colleagues in each institute have been equally rewarding. With two exceptions, we cannot single out individuals from among them. To the realism and comprehension of Carlton Wood in shaping the dimensions of the research, each participant owes appreciation. For the cheerful critiques, diligent alertness, and thorough consistency of Patricia Carlson in managing the bibliographical and statistical phases throughout the project, our congratulations and thanks.

At one point, we were of the view that the opportunity of writing the Preface to this report should be reserved for the wives and children of all staff members. They bear the costs of field research without the satisfaction of its challenges. Moreover, they have not had the

chance we have had to meet and work face to face. That occasion will mark the highest personal reward in an international project that has already brought high personal satisfaction to each of us.

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* Resigned March 1967.
† From April 1967.

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I SUMMARY AND CONCLUSIONS

Problem Definition

The extent and kind of industrialization that are desirable in cities of different size have been debated in both developed and developing countries. One school advocates, as the path to most rapid economic growth, unfettered encouragement to the observed tendency of many industries to "swarm" together in large urban concentrations. Another school argues the opposite: that developing countries should forestall the social costs of overcrowding in urban slums and other presumed costs of excessive city size by a strategy of dispersed industrial development, stimulating the economic growth of less advanced regions. Between these poles, there is a growing interest in a strategy of "selective concentration" of industries at "intermediate urban growth points," extending the matrix of market contacts and other modernizing forces effectively into the region or country. Programs and incentives to implement each of these policy preferences are found in various developing economies. Each policy advocate, however, is faced by a dearth of information on the relative costs and benefits of alternative strategies, and on locational requirements of industries that cause or permit their attraction to cities of different sizes and types.

Objective and Approach

This study is designed, in the above policy context, to measure the direct costs of equipping cities of different size for industrial development, including the costs of social infrastructure for new urban industrial employees and their families. The research is oriented primarily to the situation of developing economies and is centered on the industrial growth requirements of selected cities in the states of Punjab, Haryana, and Uttar Pradesh, in northern India.

As a specific hypothesis, the research examines the widely held belief that unit costs of incremental infrastructure for new industry tend to be relatively high in smaller cities, to decrease significantly over some intermediate range of city sizes, and to rise significantly beyond some large city size. Two tests are developed on the research hypothesis, one focused solely on the effect of city size on costs, the second examining the combined effect on costs when composition of industry varies with city size.

Scope of Cost Analysis

City size, as measured in this study by population, is an overall or gross variable that has ill-defined effects on several more specific variables that are direct determinants of costs. Other gross variables that interact with city population size in establishing patterns of relationship among direct cost variables are per capita income, levels of public investment, and city land area. These gross variables affect the following cost determinants explicitly examined in this study: (1) urban form, layout, and pattern of land use; (2) gross residential density; (3) scale and output volume of individual urban facilities and services; (4) quality or standards of service; (5) types and volumes of industrial production and employment; and (6) supply and demand position of construction labor, land, and building materials as reflected in their market prices.

In order to clarify the impact of individual variables, the study is designed to provide quantitative evidence on clearly specified sets of costs, defining the treatment of each variable. The scope of research excludes urban costs that can be quantified only by indirect measurement, such as congestion costs, or that are even more difficult to quantify, such as the human costs of slums. The multiplier effects of new industries in creating or inducing demand for additional locally produced goods and services, thereby stimulating secondary and further increases in employment and demand, are also excluded from the cost estimates.

Three new sets of information are needed to estimate urban infrastructure costs as so defined: (1) on capital and current (recurring) costs of individual facilities and services, particularly measuring economies of scale; (2) on quantitative infrastructure requirements of individual industries; and (3) on orientation of different types of industry to cities of different size. In order to identify alternative cost configurations and industrial opportunities related to size of city, a comparative international approach is used. The cost functions on urban facilities reported in Chapter III and the industrial location and infrastructure characteristics reported in Chapter IV, based on India field data and on compilation and analysis of data from U.S. and other secondary sources, are designed to be useful for project analysis and comparative research by engineers, facility managers, industrial developers, and financing agencies in other countries. Variables requiring particular attention in analyses for other cities or regions are identified in presenting the cost findings.

Procedure for Examining Region and Cities

In the selection of the study region, a principal criterion was that its cities should have similar topographic and geologic conditions, to reduce extraneous influences on building designs and construction costs. A cluster analysis of urban characteristics of 134 cities in the chosen region in India resulted in the selection of 18 cities having similar economic as well as physical conditions. In these 18 cities, information was gained through field interviews on construction, maintenance, and

operation costs of 12 facilities and services, on their levels of development and related urban characteristics, and on infrastructural and locational requirements of plants in 75 manufacturing lines. Five of the 18 cities, ranging in population from 48,000 to 1,070,000 as of 1967, were then selected for detailed estimation of incremental infrastructure costs for new industry.

In the first test of the hypothesis, incremental infrastructure costs are estimated with all factors held constant except city size. Here the incremental industry mix projected as the basis for establishing infrastructure requirements is not changed in composition, but its net output and related requirements are changed in approximate proportion to size of city. Recent manufacturing employment in the five cities is taken as the specific measure for varying the size of mix with size of city. The projected new industry mixes for each city represent an increase of 185 percent in value added by manufactu in a 10-year period.

The second test of the hypothesis estimates incremental costs when the composition of new industries in small, medium, and large cities is deliberately varied, according to locational advantages for particular industries in cities of different size.

Summary of Analytical Factors

The treatment of each cost relationship and variable is summarized as follows.

Relationship or Variable	Treatment
1. Economies or diseconomies of scale	Estimated for major facilities and their components.
2. Level of development of existing facilities	Analyzed in City Inventory and Index of Development, and tested in "off-site" cost estimates.
3. City land area and form	Effects partly tested through site selection procedure and estimate of "off-site" costs.
4. Population density	Analyzed for existing cities. Held constant in tests of incremental costs.
5. Size of incremental industry mix	Proportionate to city size.

Relationship or Variable	Treatment
6. Composition of industry mix	Held constant in the first cost test to study city size effects. Then changed to reflect industry variation with city size.
7. Facility standards	
a. Industrial	Determined by in-plant evaluations.
b. Residential	Physical requirements for water in largest two test cities and housing in largest city changed in order to maintain equivalent living standards.
8. Per capita income levels and distribution	Implicit in residential standards, i.e., held constant among test cities.
9. Multiplier or induced and indirect impact of new industry on city growth	Not analyzed. (See discussion on pages 29 and 346.)
10. Congestion and overconcentration	Not analyzed. (See discussion on pages 29, 39, and 348-349.)
11. Costs of construction labor and materials	Examined through regression analyses and cost indexes for 18 cities.
12. Cost of land	Taken into account in site selection. Not included in infrastructure costs.
13. Cost of capital	Cost estimates based on discount rate of 10 percent. Comparison with 5 percent rate shown for the principal results.
14. Time phasing of development	Not analyzed. Costs estimated for industry projection as of year 10. (See pages 276 and 358-359.)

Possible effects of those factors not quantitatively analyzed are discussed briefly below following presentation of the two tests of the hypothesis.

First Test of Hypothesis

As a basis for estimating incremental costs, the relationship of construction labor and material costs to city size was first examined for the 18 cities. It was found that costs of construction inputs do not differ systematically with city size in these cities. In cost estimates for the five test cities, therefore, no cost adjustments for construction materials and labor are made.

A review in the 18 cities of urban facilities directly used by industry--power, water, sewerage, roads--reveals no general availability of unused capacity in quantities needed for substantial industrial expansion. In the few cases where excess capacity exists, this is not consistently the case for all facilities and is not systematically related to city size.

The pattern of incremental costs on the first test is as follows. Capital costs per Rs. 1,000 value added and per employee decline by 6 percent with increase in city size from 48,000 to 132,000 population, decline slightly to the next size city, and then stabilize, instead of showing a rise in larger cities as provided in the research hypothesis. This stabilization is true up to 1,070,000 population, the limit of city size tested in the study. Expressed per Rs. 1,000 value added, capital cost in the smallest city is about 7 percent above that in the largest city. In the 132,000 city, unit capital cost is less than 1 percent above that of the largest city.

Compared to unit capital costs, which begin to level off at the 132,000 population level, annual* costs per unit of value added and per employee show a continuing small decline with increasing city size. This is because of economies in annual maintenance and operation costs with increase in scale of facility, not because of capital cost differences. Annual costs per Rs. 1,000 value added range from Rs. 145 to Rs. 128 from the smallest to the largest cities.† The increase in unit annual costs from the 1,070,000 city to the 323,000 and 212,000 city is about 2 percent, to the 132,000 city about 4 percent, and to the 48,000 city about 13 percent.

The relative weight of the principal elements in total infrastructure costs for industrial development varies with size of city through the interplay of three major factors: differences in physical requirements for achieving equivalent standards; differential economies of scale, both in capital and current costs; and small changes in circulation or distribution costs per acre of development site. These effects are seen most

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* Annual costs = annual capital cost equivalent plus annual maintenance and operation costs. See pages 55-58.

† Rs. 7.50 = US$1.00 at the official exchange rate during the period of the field survey, 1967.

clearly, in what follows, in the elements that account for the largest share of annual costs: housing, schools, power, hospitals, water, and roads.

Expenditure of public funds is assumed to be required for 20 percent of the urban housing of new industrial employees and their families. Housing on this basis accounts for the largest share of annual costs, increasing from 19 percent in the 48,000 city to 25 percent in the 1,070,000 city. Unit costs of housing (excluding land cost) are constant in all except the largest city, where the need for multistory dwellings increases unit housing costs by 16 percent.

Education, limited here to primary and secondary schools, accounts for the next largest share of annual costs. More or less constant in unit costs, schools account for about 18 to 20 percent of the annual infrastructure cost bill in each test city.

Power distribution costs, which exhibit moderate economies of scale, are the largest direct industrial cost element. From the smallest to the largest city, the total annual cost of urban power distribution declines irregularly from about Rs. 23 to about Rs. 19 per Rs. 1,000 of value added by manufacture. Scale economies are substantial in substations and in maintenance and operation costs, but their effects in the total power costs analyzed are attenuated by relatively constant unit costs of distribution mains and lines per developmental acre.

Hospital costs per new urban industrial employee drop sharply from the 48,000 city to the 132,000 city, and then, except for a rise in the 323,000 city, fall gradually to the largest city studied.

Urban water supply for expanded industry and its employees exhibits significant scale economies. The annual cost of water per industrial employee in the 48,000 city is 58 percent above that in the 1,070,000 city, despite the fact that the average daily civic requirement in the two largest cities is a third higher than in the three smaller cities--40 gallons as against 30 gallons per capita. Whereas water accounts for over 11 percent of total infrastructure cost in the smallest city, its share falls to 8 percent in the largest city, about equal to that of roads.

Road costs per Rs. 1,000 value added decline very slightly over the range of cities from 48,000 to 323,000 population, and increase slightly in the 1 million city. Unit costs for site development are virtually constant, rising from 6.8 to 7.9 percent of annual costs over the city size range.

Sewerage costs, from 4.3 to 5.0 percent of the total, exhibit moderate scale economies. It should be noted that in more developed systems than those provided in the study region, economies of scale in sewerage systems would tend to be more or less comparable to those for water systems.

Unit costs for telephones, fire and police protection, and refuse disposal are virtually constant; their combined share of annual costs rises from 3.7 to 4.4 percent from the smallest to largest city.

In sum, these moderately divergent cost movements largely neutralize each other, except between cities of 48,000 and 132,000 population. The conclusion of practical import is that beyond a city size of about 130,000 population, unit cost differences for the projected volume and types of industrial infrastructure are insignificant. The results substantiate the first part of the cost hypothesis--that unit costs decline from the smallest to the next size city--but do not support the hypothesis of rising unit costs in large cities, at least for the range of cities and cost elements studied.

Allocating costs between industrial and residential areas, it is found that social infrastructure accounts for 73 to 76 percent of incremental infrastructure costs. Social infrastructure costs per industrial employee move irregularly in a modified U-shape, accounting for most of the decline in unit costs from the 48,000 city to the 132,000 city, reaching their lowest level in the 212,000 city, increasing slightly for the 323,000 city, and holding even at that level. Infrastructure directly serving industry accounts for 24 to 27 percent of incremental costs. Costs of direct industrial infrastructure per Rs. 1,000 value added decline consistently, but in small amounts, over the full range of cities studied.

Second Test - Varying Composition of Industry with Size of City

Many of the industries analyzed in the field study have relatively wide options as to location, including opportunities to locate profitably in cities of different size. The numerous factors that influence industrial location, however, coalesce in varying combinations to encourage certain types of industries to locate in cities of particular size. Such attractions depend on cities' levels of development and regional advantages, factors that in turn shape future city growth and size.

The study develops location quotients for specific industries in the India field region and in the United States, demonstrating patterns of relationship between type of industry and city size. Coupled with interview data and judgments on the importance of factors such as market accessibility, labor skills, and specialized services, evidence on city size is brought together at the end of Chapter IV to establish indicative lists of industries: a core list of "ubiquitous" industries with promise in cities of most sizes in the region, and lists of industries oriented particularly to small cities of 20,000-50,000, medium cities of 100,000-250,000, and large cities of over 500,000.

These lists of industries are used in shaping the second test of the cost hypothesis. In this test, the composition of industry is changed with city size. Infrastructure requirements are thereby also significantly

changed. Compared to the median or proportionate industry mix, so termed because it varies simply in proportion to city size in the first test of the hypothesis, the new mix oriented to small cities has much higher requirements of labor, floor space, power, water, and transport per unit of value added. The large city mix has lower unit labor, floor space, and transport requirements than the proportionate mix, but somewhat higher power and water consumption. Costs are correspondingly influenced.

Costs per Rs. 1,000 value added for the more specialized mix in the large city are somewhat lower than for the proportionate mix of the first test. In the small city, unit costs of infrastructure for the small city mix are much higher than for the proportionate mix. Cost differences between cities on the second test are greater per unit of value added than per employee, because value added per employee differs widely with the variation in industry mixes. It is to be stressed, however, that such differences result primarily from product and process differences among industries, not from differences in productivity or from city size in and of itself.

Direct industrial costs increase more than social infrastructure costs for the specialized small city mix, because of the change in direct infrastructure requirements. On the other hand, economies of scale for the quantities of power and water required by the specialized mix result in lower costs per installed kva or per million gallons than for the proportionate mix in the small city. Unit costs of these specific infrastructure facilities are thus lower for a suitable mix of industries oriented to city size than for industries located without regard to city size or combined infrastructure needs.

The policy significance of results on the second test clearly rests on the degree to which industries concerned are sensitive to specific infrastructure costs. This may be gauged from the use-intensities of different industries for power, water, transport, and floor space, as classified in Chapter IV. Industries ranked as high or very high users of a specific infrastructure input can in general be regarded as sensitive to its unit costs. In any particular case, of course, the degree of cost competition would determine the effective impact of infrastructure costs. On the whole, industries of the types that constitute the small city mix are heavier users of direct industrial infrastructure per unit of net output than industries in the medium or large city mixes. This suggests that in order to overcome the modest cost disadvantage indicated by the first test, small cities must be favored by local cost factors, or must be otherwise capable of attracting a volume of industry that permits scale economies in critical infrastructure inputs.

Thus, in selecting smaller cities for promotion as "growth centers," especially for industries based on agricultural or forest resources, the role of physical infrastructure and local cost factors associated with the needed infrastructure are of particular importance.

Influence of Key Assumptions and Uncosted Variables

The size of industry mix taken as the basis for cost estimates, derived from national input-output projections of industrywise growth, is substantially larger than that indicated by other projections made later. Other things being equal, the principal effect of a smaller industry mix would be to shift the unit cost curve somewhat to the right. That is, the decrease in unit costs would start to flatten out at a city size larger than 130,000 population. On the other hand, inclusion of multiplier or secondary effects of new industry in inducing new local demands and employment would shift the unit cost curve to the left. The net result of these opposite influences could be determined for any particular set of industries and estimate of induced effects with the help of cost and requirements data presented in Chapters III and IV.

The weight of housing in infrastructure costs is so great that any marked change in the level of housing included in the estimates would drastically alter the cost conclusions. If no new urban industrial housing were provided (instead of the 20 percent covered in the estimates), unit costs of infrastructure would continue to decline substantially through the largest city studied. If 100 percent were provided through public expenditure, on the other hand, diseconomies of large city size would become pronounced as a result of the increased requirement for multistory housing. Given the focus of the study on costs that must normally be met by public funds in order to equip cities for new industry, we consider the 20 percent assumption most appropriate. However, if the standpoint is that of the full social costs associated with collective effects of city size, the cost disadvantage of housing requirements in the largest city must be recognized.

The incremental cost estimates provide a clearcut measure of the effects of city size without attempting to introduce the many contrasting density patterns that exist in different cities, and without considering congestion costs. Since differences in density per developed acre are not correlated with city size in the 18 cities surveyed, no basis was established for interpreting variation in density or related costs as a function of city size. The possibility of lower construction standards in cities of lower density and size was not examined, this would require detailed analysis of economic trade-offs between first cost, maintenance, and renewal costs in the context of urban expansion. Further research on these factors and on congestion costs is clearly needed. It is quite possible that at some point the effect of a combined change in size and density may cause a qualitative change in the cost function. Without an adequate estimate of congestion costs, in particular, it is not possible to evaluate the full social costs associated with city size and density variations.

Land costs were omitted from the cost estimates to permit comparison of infrastructure costs without the influence of local land price variations. For the five test cities, land prices vary greatly without relationship to city size. The share of land costs in total costs of infrastructure development would range from about 17 percent to as high as 47

percent. The need is evident for further research on land costs, oriented to policies for urban land taxation and acquisition.

Calculation of annual capital cost equivalents is based on a 10 percent interest rate, which is closer to the opportunity cost of capital in most developing economies than are the bookkeeping rates of about 5 percent used by many public agencies. The cost difference which results from using this more realistic cost of capital (10 instead of 5 percent) amounts to Rs. 37-39 per Rs. 1,000 value added. At the lower rate, absolute cost differences between the smallest and largest city are somewhat less, but relative differences are slightly more.

Conclusions for Urban Industrial Development in a Regional Context

Unit costs of an increment of infrastructure, in terms of public investment and for a large industrial expansion, are virtually equal for cities above 130,000 population in this region. This offers a wide range of city sizes for industrial location choices. When coupled with emerging industrial patterns in cities of different size, observed in the field study, this cost finding suggests that the search for opportunities for industrial agglomeration may start in cities of around 130,000 to 300,000. Such a policy would take advantage of the phase of increasing benefits to agglomeration in places where these benefits are not yet countered by possible social costs of the largest cities. The report proposes, as part of further research, steps to identify and equip cities of 130,000 to 300,000 that have promise for types of manufacturing that foster interindustry linkages and agglomeration economies, as listed in Chapter IV.

During the past decade, cities in the 130,000-300,000 population range in the northwest part of the region have achieved initial agglomeration economies which also show evidence of extending outward to support industrialization in certain smaller cities, well supplied with local initiative and regional linkages. For such smaller cities, road and telephone linkages with specialized industries of medium and large cities substitute nearness in time for nearness in space. Industrial productivity and underlying economic conditions in this relatively compact subregion are currently more favorable than in central and eastern parts of the study region, but the contribution of linkages between smaller cities and medium size subregional centers is suggestive. Research toward selective identification of growth centers in other parts of the region, which warrants high priority, should examine needed intraregional linkages and also their probable contrasting impacts on opportunities for ubiquitous industries and for specialized industries in smaller cities.

These conclusions confirm the importance of establishing a regional basis for industrial development efforts, identifying cities that are suitably located and can be efficiently equipped for different types of industries, and fostering effective complementarity among cities of different size.

The recommended policy of selectivity in promotion of different industries in different size cities suggests that emphasis in the 1 million city be on technological industries oriented to the city's new institutional resources. As against large net industrial expansion in this city, the case is strong for adjustment assistance to facilitate transfer of workers and resources from the city's major depressed industry to other industries, coupled with urban core redevelopment.

Wider Relevance for Urban Development

Questions of the applicability of the study's cost findings to a particular city or their transferability to other regions and countries follow naturally from these overall conclusions.

We are skeptical, first of all, as to the relevance of a particular city population figure, such as 130,000, to other countries. Differences in climate and living conditions, income, industrial demands, and urban density cause city population size to have quite different significance in different geographic and cultural environments. Statements on parallel or related size scales for comparison of costs or comparison of industrial opportunities can only emerge from wide international collaboration and study of contrasting circumstances

Nevertheless, conclusions on the shape of the unit cost curve for urban industrial infrastructure can be developed in other regions through application of variance or sensitivity analysis to the major cost components set forth in this report. Water systems are a prominent case in point. Scale economies for water systems based on underground sources, although substantial, as in the cities studied, are apparently less significant than for river sources, which call for complete water treatment plants. On the other hand, per capita water use of 30-40 gallons per day, the basis for the study estimates, may need revision to meet use levels in other countries. For regions where urban water facilities present variations of this magnitude, cost information provided in Chapter III can be adapted to an assessment of water system costs. The net effect could then be incorporated in re-evaluating, for cities in the given region, the full bill of infrastructure costs developed in Chapter V.

In order to develop a firm understanding of costs as a factor in urban facility planning, the present report is best viewed as one step in a process to be carried further by operating, financing, and research agencies. Comparative cost information is presented here in a form that can be used or adapted by municipal, state, and national agencies in engineering economic analyses and capital budget analyses being made for urban investment decisions. The study's cost data on economies of scale are particularly applicable in evaluating expansion plans for power, water, and sewerage systems. On the other hand, to analyze trade-offs in first costs versus user and maintenance costs, in relation to projected demand, much additional local cost information would be required. In general, in applying the cost methodology and data of the report, it is obvious that local material and labor costs, design criteria, and construction technology requirements must be substituted for many of the details.

The critical matter of time phasing of facility investment in relation to city land use planning and development is beyond our present scope. As described in Chapter II, to avoid obscuring the effects of city size by introducing features unique to each city, selection of sites for comparative cost estimates was done in terms of concentrated development of new industrial and housing areas, as opposed to infilling in smaller, scattered increments. Although the chosen sites are compatible with city master plans where these exist, industrial expansion by phased increments would call for much closer dovetailing of siting decisions with the normal processes of city land-use planning and acquisition. Similarly, closer phasing would be required vis-à-vis the existing capacities and planned expansion programs of principal infrastructure facilities.

Direct cost trade-offs for alternative development densities at the neighborhood level can to a considerable degree be established by local agencies through engineering cost analyses. The more complex influence of density on congestion costs, however, especially for citywide systems, calls for major research on a comparative basis. The report suggests an approach to establishing a methodology and procedure for such comparative research as an integral part of urban traffic and development studies.

Our experience in this project indicates that applying up-to-date criteria and analytical techniques to acility investment decisions in developing cities will require increased collaboration--between industrial developers, departmental engineers and facility managers, city planners, and budget analysts in city and state finance agencies. A large part of such analysis is operational, pointed to imminent financial commitments. For this reason, professional staff members of responsible action agencies often have little if any opportunity to integrate their experience and techniques with those of related disciplines in joint, longer-term approaches to urban and industrial development. Industrial investors, moreover, frequently do not find in developing cities a focal agency that is equipped to deal comprehensively with infrastructure and site requirements.

The present report therefore points to two pervasive needs in promoting industrial growth and better urban development: more adequate funding of interprofessional collaboration in both operating and research programs; and more deliberate, broad-based exchanges between public agencies and industrial investors whose combined resources will shape the cities of tomorrow.

II POLICY ISSUES AND ANALYTICAL FRAMEWORK: THE RESEARCH OBJECTIVE

The influence of city size on industrial infrastructure costs is an issue central to policies of industrial, regional, and urban development. In developing regions, attention must be given to those minimum sets and costs of urban facilities which, in conjunction with appropriate economic activities, create conditions for profitable industrial growth. The tendency for development to occur initially in a limited number of centers and regions impels policy makers in less advanced regions to search for methods of attracting catalytic industries to suitable local centers as a means of stimulating economic growth. Finally, citizens of developed as well as developing economies are concerned with economic and social costs of excessive city size, to which over-concentration of industry may contribute. No adequate estimate is available of the benefits and costs of alternative urban industrial policies, although debate on policies of decentralized industrial development has flourished for at least half a century.

The present study seeks to mount a systematic attack on estimation of costs relevant to these issues. The objective of the research contract is "to measure the comparative costs of supplying the physical and social infrastructure facilities required by industry in urban centers of different sizes." The contract further states that in the field study, "the contractor will test his hypothesis that costs of industrial infrastructure are significantly related to size (scale) of urban centers."

In the India Research Plan, the research objective is further detailed as follows:

- To develop systematic information on costs of infrastructure in a form useful to planners, industrial development agencies, urban development organizations, project engineers, and financing agencies in estimating and evaluating the investment needed to provide these facilities for support of industrial development in urban centers of different size.

- To analyze and interpret such cost information as an important element in the wider issue (beyond the scope of the present project) of appropriate policies to promote industrial growth and employment opportunities outside major cities and to raise overall levels of regional economic activity.

- To develop and test methodologies through which cost analyses may be applied by planning and research agencies in other developing regions and countries.

As a guide to analytical clarity and control, the cost hypothesis is spelled out explicitly in the India Research Plan and India Research Design. The hypothesis states

> that there is a minimum economic base, related to city size, below which unit costs of incremental infrastructure required for industrial growth are very high;
>
> that in cities above this minimum size, the unit costs of incremental infrastructure decrease significantly with increasing industrial requirements over some range of city size;
>
> and above this range, unit costs of incremental infrastructure increase significantly with increasing industrial requirements.

Before the project's specific approach to infrastructure costs is defined, it is desirable to give a brief review of wider issues of industrial, regional, and urban development to which the cost analyses relate.

Industrial, Regional, and Urban Setting of the Study

The Issue of City Size in Regional and Industrial Development

Industrialization--along with progress in other important fields such as agriculture, commerce, and education--is one of the requisites for economic advancement in less developed countries. Progress in manufacturing is of strategic importance because of its exceptional tendencies to stimulate other new activities. The spatial pattern of industrial development may have major influence on rates of growth, distribution of income, and other types of national objectives.

Polarization of industry at one or a few centers in the early stages of industrial growth is a common phenomenon, considered by many leading students of regional development to be inevitable. The fundamental questions that this poses for those concerned with national or regional development is whether or to what degree an attempt should be made to modify extreme polarization of industry and, if an attempt is to be made, what methods are likely to be effective and what costs and benefits are likely to arise from them.

Many reasons why industry should tend to agglomerate are offered in the literature on industrial location, spatial organization, regional development, and urban economics, but as Robert Spiegelman has shown, a completely satisfactory general theory has not yet been formulated.*

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* U.S. Dept. of Agriculture, Economic Research Service, Agricultural Economics Report No. 96, Analysis of Urban Agglomeration and its Meaning for Rural People, by Robert G. Spiegelman, Stanford Research Institute, Washington, June 1966, 24 pp. The discussion which follows on agglomeration draws closely on Spiegelman's summary and analysis.

Earlier theories demonstrated that, under certain assumptions, transport costs and discontinuities in the transport cost function tended to cause a clustering of enterprises. Recent works indicate that optimum or stable equilibrium solutions to the location problem are unlikely when the complexities of the real world enter the calculations. Charles Tiebout has shown* that a maximum profit solution to location for a company with several sources of raw materials and a given market is possible only under the following conditions:

1. Gross revenue from sales is constant regardless of location

2. Nontransport costs are independent of location

3. Transport costs are a linear function of distance

When production costs and prices vary with location, there may not be a maximum profit curve. Leon Moses has indicated that if inputs are substitutable, there is no single optimum location.†

Other theorists emphasizing the dynamic process and external advantages of agglomeration provide further rationale for extreme clustering. Some French economists have put forth the view that growth starts at certain points in space for a variety of reasons, mostly related to the presence of an innovating spirit. A time sequence of geographic interindustry linkages is generated that tends to cause further growth at the points of innovation. Interindustry linkages, however, do not explain the clustering tendency of footloose industries with weak interindustry requirements, and do not adequately explain the general extent of the metropolitan areas' force of attraction.

A somewhat different explanation has been provided by theorists such as Hoover,‡ Friedmann,§ and Alonso.** As the key elements of original agglomeration, they have stressed the role of access to markets and, through commuting, to labor resources of adequate size and variety, coupled with transport cost minimization by location at hubs of transport networks. Further agglomeration is related to the buildup of external advantages such as the generation of labor skills, the multiplication of specialized services, and geographic proximity of interindustry linkages. However,

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* Charles M. Tiebout, The Community Economic Base Study, Committee for Economic Development, Supplementary Paper No. 16, New York, December 1962.

† Leon Moses, "Location Theory, Input-Output, and Economic Development: An Appraisal," Review of Economics and Statistics, Vol. 37, 1955, pp. 308-312.

‡ Edgar M. Hoover, The Location of Economic Activity, McGraw-Hill Book Company, New York, 1948.

§ John Friedmann, "Locational Aspects of Economic Development," Land Economics, Vol. XXXII, No. 3, August 1956, pp. 213-227.

** William Alonso, "Location Theory," in reference 7 (see Annotated Bibliography at end of report), pp. 78-106.

in view of the fact that many transport nodes do not develop, a more comprehensive theory of agglomeration is needed. At the present time, not enough is known about agglomeration to indicate in what degree it represents a response to economic and noneconomic forces; whether there are alternative ways of achieving the economies that agglomeration may bring; or what costs or economic losses might result from measures diminishing the tendency of industries to agglomerate.

A limitation of much of the inquiry so far into the cause of agglomeration is that much of it has been primarily concerned with explaining agglomeration in industrially advanced countries. Much more empirical work is needed in testing the applicability of agglomeration theories to the conditions of the newly industrializing countries where major differences in the economic and political structure may cause different weights in factors which influence industrial location. The importance of these differences and their major consequences in selection of regional development policies has been underlined by John Friedmann,* who indicates that regional development programs may be of great value in countries undergoing transition to industrialism, but tend to be weak instruments in highly integrated market-oriented economies such as the United States.

The tendency of industry to agglomerate is not without its disadvantages, and these tend to be particularly acute in less developed countries. Five common situations may make it worthwhile to exert some level of effort toward achieving a wider regional distribution of industrial growth.

1. Economic Mislocations of Industry. Perhaps a substantial part of the polarization of industry results because entrepreneurs are more aware of the opportunities and locational advantages of the principal industrial centers than of smaller ones. Investment decisions are often not made on the basis of full information and comparative analysis, but by efforts to duplicate observable success Inertia, personal considerations of top management, relocation costs, and uncertainties may be important related factors that keep enterprises in major centers even though other centers would provide a more economic operational base.

2. Congestion Problems in Major Urban Areas. Difficulties in the efficient planning and managing of relatively large urban areas such as Calcutta or Lima often lead to a critical accumulation of economic, social and political problems. This situation may indicate the desirability of diverting further growth from such cities to other areas.

3. Untapped Resource Regions. Major areas that are not yet undergoing development may have resources of special value for accelerating the general development of the economy, either immediately or over the long term.

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* John Friedmann, "Regional Planning as a Field of Study," in reference 7, pp. 59-72.

4. Dual Economies or Lagging Regions. Where major populated areas of the economy are not touched by industrialization or other developments taking place in advanced regions, some degree of decentralized location of industry may be desirable as a means of setting the growth process in motion.

5. Political and Welfare Considerations. Some decentralization of industrial growth to lagging areas may also be desirable to achieve a more equitable or simply wider regional distribution of income and employment. The motive for special efforts to widen the regional decentralization of industrial growth is based primarily on the view that leading industrial centers, at least in newly industrializing economies, tend to sap the industrial growth potential of other areas by attracting from them both savings and the ablest human resources. Governments tend to tailor their infrastructure investments and general economic policies more to the needs of present industrial centers than to other sections of the country. Aside from the equity issue, sharp regional political differences often make some decentralization of industry a prerequisite for achieving the unity of action needed to implement development measures.

The disagreement over the best strategy of industrial location for economic development revolves in part around different assumptions as to the possibility and urgency of stimulating change in agricultural activities in backward areas by the proximity of industrial enterprises or modern urban facilities, which tend to develop around agglomerations of industry. Interdisciplinary studies have brought increasing recognition that modernization is "a dynamic process occurring through the interaction of the economic, social, and psychological forces in a society."* They also underline the need to bridge the communications gap between urban enclaves and the residents of rural areas. However, just how or to what extent this may be achieved through a greater dispersal of industrial growth is yet to be established.

Studies on the relationship between agricultural development and the proximity of industrial centers suggest that industrial location patterns which stimulate agricultural development may more than compensate in this way for higher infrastructure costs or slower industrial growth that may result. T. W. Schultz advances the view that economic development occurs in a locational matrix and that agricultural prosperity is influenced by proximity to urban centers of development.† W. H. Nicholls concludes from detailed studies in South Carolina and Georgia that "local industrial-urban development made an important positive contribution to the efficiency of

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* M. F. Millikan and D.L.M. Blackmer (Eds.), The Emerging Nations: Their Growth and United States Policy, Center for International Studies, M.I.T., Cambridge, Mass., 1961.

† Theodore W. Schultz, The Economic Organization of Agriculture, McGraw-Hill Book Company, New York, 1953.

local factor and product markets, thereby greatly facilitating the transfer of excess labor out of agriculture and of needed capital into agriculture . . ." One policy implication which he draws, and also regards as applicable to underdeveloped countries is: ". . . insofar as it is not inconsistent with fundamental economies of location and scale, the more widely dispersed such industrial urban development, the more generally can agricultural productivity be increased."*

John Lewis's study of India argues even more strongly for dispersal of industrial growth, specifying towns with a population 20,000 to 300,000 as being most suitable: "Furthermore, by maximizing the average proximity of agriculture to concentrations of industrial and commercial activity, a pattern of comparatively (but not unrealistically) dispersed industrialization would help to provide the kind of market environment that . . . agricultural development so urgently needs. Indeed, town-centered development would supply the necessary frame of the whole network of development sequences, linkages, and feed-backs upon which the successful transformation of the Indian countryside so largely depends."†

There is, however, a question whether centers below some size can absorb any industry without considerable expansion in infrastructure. Experience with industrial estate programs in India and Central America suggests that most centers of less than 50,000 to 100,000, in order to induce industry to locate in relatively untried locations, must provide a minimum increment of infrastructure which is larger than can be fully utilized in the near future. Whether infrastructure can be added in medium or large centers on a basis more nearly in phase with demand appears to depend on how well planned such centers are. In congested and badly planned centers, a small amount of additional industry may necessitate enormous infrastructure expenditures since, unless major parts of the city are removed and reconstructed on a planned basis, the burden of additional enterprises may paralyze the city's functions.

This debate, even on the more easily quantifiable issues, is muddied by the fact that even in the case of a specific country at a specific moment of time, the costs and benefits of diverting the location of a portion of new enterprises from metropolises to smaller centers vary greatly not only with the size and other characteristics of urban centers in question but also with (1) the spatial relationship of a given center to other urban centers and to rural markets and sources of supplies; (2) the extent and quality of the transportation and communication linkages; and (3) the type and size of industrial units and the extent of industrial aggregation to be located in a particular center. As a result, the case is strong for deferring the idea of finding an optimal city size in favor of determining merely the minimal efficient size for particular new developments.

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* William H. Nicholls, "Industrialization, Factor Markets, and Agricultural Development," reference 7, pp. 440-461.

† Reference 14, pp. 179-180.

Theories on the Regional Distribution of Urban Centers

A quick overview of the outstanding theories on urban places and their relationships within a regional context can bring out the implications that regional patterns of urban settlements have for economic development. Although the main contributions to the analysis of urban location and hierarchies of function do not provide all-inclusive, ready formulas for general application, they do offer powerful theoretical as well as empirical foundations for local analyses to be undertaken for different urban areas in developing countries.

Walter Christaller. Christaller's theory on a hierarchy of central places which he set forth in Die zentralen Orte in Süddeutschland,* presents possibilities for the analysis of urban patterns in developing countries since it applies primarily to preindustrial communities. While earlier theories by Johann von Thünen† and N.S R. Gras‡ referred primarily either to one urban nucleus and its hinterland, or to a combination of several nuclei in a system of interdependent parts, Christaller related the spacing and size of these central places into a regional constellation (Gestalt), classifying the centers by size and in categories by which the largest central places also perform the largest number of services. The central place is a center of trade where goods and services are assembled and dispersed to the hinterland.

Christaller formulated three principles relating the size, number, and distribution of central places. These are summarized below from Boskin's critique and translation of the Christaller work:[3]§

1. Marketing principle. This classifies supply types of places by the service functions they perform, size of population, distance between them, and size of tributary area.

2. Traffic principle. This postulates six radiant main highways from the center to six satellites, the smaller places being serve by feeder lines.

3. Political-social (administrative) principle. The nucleus is the capital (or a central place of higher rank) surrounded by satellite places of lesser rank.

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* Walter Christaller, Die zentralen Orte in Süddeutschland, Gustav Fischer Verlag, Jena (Berlin), 1933.

† Johann von Thünen, Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, Hamburg, 1826.

‡ N.S.R. Gras, An Introduction to Economic History, Harper & Bros., New York, 1922.

§ Superscript numbers refer to sources listed in Annotated Bibliography at end of report.

Christaller's theory thus provides clues as to how the current hierarchical pattern of central places evolved and offers a basis for the projection of future patterns of settlement in the regions.

August Lösch. In The Economics of Location* (first published in German in 1940), Lösch further develops Christaller's central place theory and attempts to integrate the principles of urban structure with those of industrial agglomeration. He presents an ideal "economic landscape" of hexagonal forms for market regions surrounding each center of production or consumption. He divides urban areas into (1) simple market areas, (2) nets of such areas, and (3) systems of nets or regions. Although the market areas for products may differ, at the point of minimum market size agglomeration economies begin, inducing compromises in the size of various market areas and resulting in a common hierarchy of distribution centers arranged in a hexagonal pattern, radiating out from the largest to the smallest center. A link is then found between the sizes of market area for various industries and the sizes of cities. He indicates that in reality there is much overlap so that a clear economic region is an accident, but he affirms that beneath a sphere of irregular market areas, we find a regional substructure of varying importance almost everywhere.

Walter Isard. Isard has approached the study of location by combining the von Thünen, Löschian, and Weberian† theories. As Vincent Whitney has indicated,‡ Isard sought to develop "interregional frameworks which express all kinds of linkages in proper relation to one another, . . . as a complete and self-sustaining closed system." Isard's main concern in his study, Location and Space-Economy, was the development of an urban land use theory.[11] By incorporating Bogue's population density variations§ with Lösch's theory of hexagonal patterns, Isard produced a theoretical framework which can be adapted to urban areas as well as regional patterns of location. Lösch's homogeneous hexagonal system of nets of market areas oriented toward the common center (the metropolis) was graphically interpreted by Isard with six center-oriented sectors which concentrate production, thus reducing the costs of distance to the central market.

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* August Lösch, The Economics of Location, trans. from the second revised ed. by William H. Woglom with the assistance of Wolfgang F. Stolper, Yale University Press, New Haven, Conn., 1954, 520 pp.

† Alfred Weber, Über den Standort der Industrien, Tübingen, 1909, trans. by Carl J. Friedrich, Alfred Weber's Theory of the Location of Industries, Chicago, Ill., 1929.

‡ Vincent H. Whitney, "Potential Contributions of Regional Science to the Field of Sociology," The Regional Science Association Papers and Proceedings, Vol. 3, 1957, pp. 24-28.

§ D. J. Bogue, The Structure of the Metropolitan Community, University of Michigan, Ann Arbor, 1949.

Brian J. L. Berry. Berry put forth the following set of relationships to explain central place systems: the trade area served by a central city is a function of the density of the population in the trade area and the population of the central city; and the population of the central city is a function of the number of central functions performed by that city (i.e., the number of separate types of businesses). The essence of central place theory is that transport costs create varying geographic ranges for goods; the wider the range, the more the output tends to concentrate in large places.

If interurban trading relationships posited by central place theory are correct, then there should also be some stable size relationship among cities. According to Berry, two kinds of city size distributions are recognized: (1) rank size or lognormal distribution in which urban centers are of regular graduated sizes, and (2) primate distribution in which there are one or more dominant centers and a deficiency of intermediate size centers. In his study, "City Size Distributions and Economic Development,"* covering a variety of countries, Berry found:

> There are no relationships between type of city size distribution and either relative economic development or the degree of urbanization of countries, although urbanization and economic development are highly associated. It appears that there is a scale from primate to lognormal distributions which is somehow tied to the number and complexity of forces affecting the urban structure of countries, such that when few strong forces obtain primacy results, and when many forces act in many ways with none predominant a lognormal city size distribution is found. Simplicity was associated with indigenous political and administrative controls exercised from orthogenetic primate cities, with dual or multiple colonial economies and controls exercised from heterogenetic primate cities, and with empire capitals, in all cases also combined with small countries. Note that in most instances of primacy these statements apply only to the primate cities themselves, for the system of smaller urban centers is generally distributed lognormally. Complexity was associated with specialized economies, but also with countries which have strong urban traditions and long histories of urbanization, and was found in countries of every size.

Three themes central to the present study may be derived from the above summary statements:

1. Differentiation of function is an important feature of the real world of cities, and may extend to the subclasses or types of

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* Brian J. L. Berry, "City Size Distributions and Economic Development," Economic Development and Cultural Change, Vol. IX, No. 4, July 1961, pp. 573-588.

manufacturing industry that tend to prosper in different types and sizes of city.

2. Order or hierarchy among cities and their spatial functions are instructive as guides to investment planning and promotion. As Friedmann points out, ordering in development plans for a specific region need not conform to a closed or "nested" hierarchy of urban centers; "rather, it suggests the 'weak' or 'partial' hierarchy described by Duncan and his co-workers."*

3. Growth of cities may be shaped by forces of either multiple or polar causation, as perceived by Berry in the above observation on lognormal and primate distributions. Multiple causation and functional differentiation are thus forces of particular significance to the emergence and growth of urban centers of different size.

Primacy, Agglomeration, and Selective Concentration

Observing that urban policies which try to steer development away from major metropolises and regional policies which try to promote less developed regions "often converge and complement each other,"† Alonso has undertaken to show "that these complementary policies may often be detrimental to economic growth." Citing evidence that primacy or polarization increases during the "take-off" stage, Alonso stresses the importance of a substantial concentration of economic activities to achieve that "critical mass" or "threshold" at which external economies and active information flows begin to raise productivity and generate further growth. "Considerable evidence conforms to a belief in increasing returns to urban scale . . . [E]ven if costs rise after a certain point, where productivity is rising faster (by reason of external economies or economies of scale) big cities will yield a greater net return per worker or inhabitant than smaller ones. Thus, even under a condition of rising marginal costs, net marginal product per capita may not only be positive, but increasing."‡ On the other hand, as economies mature, Alonso suggests that primacy decreases: "the largest cities continue to grow in the mature stage of the economy, but secondary centers grow faster."

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* Reference 5, p. 219. See Chapter IV for a discussion of Duncan's work on urban hierarchies.

† William Alonso, "Urban and Regional Imbalances in Economic Development," Economic Development and Cultural Change, forthcoming.

‡ Ibid. The parenthetical reference to economies of scale is unclear, since by definition, if costs have turned upward, the phase of diseconomies of scale has been reached. This may represent lack of distinction between economies of scale in the public and private sectors; see Spiegelman, op. cit., p. 11.

As Alonso points out, these arguments exist amid "a paucity of facts." For comparable industries or occupations, his own evidence for increasing returns is confined to "as yet preliminary studies" for the United States which show that "for a great many manufacturing industries value added per worker rises with urban size, although there may be a downturn after one and a half or two million population."* Interpretation of this information as evidence of external economies would depend heavily on the level of aggregation used to define a manufacturing industry, as well as on knowledge of capital intensity, market structure, and relative profits. In turn, evidence on increasing costs is slight. Tangri has suggested that per unit costs of social services may rise in India above city populations of 400,000 to 500,000, but cites no supporting data.† Wurster cites estimates of substantially increasing costs per capita for overall residential site development in cities in the Delhi area with increases from 25,000-50,000 population to 50,000-500,000 and then to over 500,000; however, the dwelling standards on which these costs are based change with city size but are not specified in the published material, so that comparison is not possible.‡

In contrast to the tenor of the above discussion, Friedmann holds that posing the issue as "concentration versus dispersal" raises a false dichotomy.§ He expands Rodwin's strategy of "concentrated decentralization"** into a threefold approach to transformation of the space economy through encouragement to "metropolitan regional economies," "development corridors," and "core regions at the periphery".†† These concepts of spatial organization have been applied by Friedmann in collaboration with the Corporación Venezolana de Guayana in formulating a regional policy specific to the conditions of Venezuela. First-order, second-order, and third-order core regions are projected and mapped to 1990. Each is expected to stimulate growth of fourth-order "local service centers." The nuclei of core regions are eight cities seen as ranging from 500,000 to 4.5 million inhabitants by 1990. Fourth-order centers are those focal places, 15 in number, expected to reach a population of at least 50,000 and ranging up to 300,000 by the end of the projection period.‡‡

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* Ibid.

† Shanti Tangri, "Urbanization, Political Stability, and Economic Growth," in reference 22, pp. 213-239.

‡ Catherine Bauer Wurster, "Urban Living Conditions, Overhead Costs, and the Development Pattern," in reference 22, pp. 277-295.

§ Reference 5, p. 52.

** Lloyd Rodwin, "Metropolitan Policy for Developing Areas," in Walter Isard and John H. Cumberland (Eds.), Regional Economic Planning: Techniques of Analysis for Less Developed Areas, Organization for European Economic Cooperation, Paris, 1961, pp. 221-232.

†† Reference 5, p. 213.

‡‡ Reference 5, pp. 217-241.

The principle of "selective concentration"[152] has thus been applied by practitioners in Venezuela in specific regional and urban development plans. Friedmann acknowledges a lack of quantitative support for certain projections used in these plans. Indeed, the lack of empirical evidence to determine relevant sizes of region and growth poles is one burden of Alonso's critique of the strategy of concentrated decentralization. Questions on which comparative evidence from different regions is needed in order to implement policies of selective concentration would include: What operational guides to selection of centers can be developed? What sizes of center contribute to effective spatial hierarchies of related functions in various regions? What division or proportioning of functions is appropriate? What kinds of industries are promising for different types and sizes of center? What assessment can be made of the benefits and costs of concentrating particular functions, industries, and related infrastructural facilities in various centers? In different regional contexts, how close or concentrated should growth centers be? What spatial linkages among centers are most crucial? Assuming that partial answers to such questions can be established, what policy and program instruments will be effective in stimulating growth of the constellation of promising centers?

The city size dimension in these questions is central to the present study. We have in view a span of city sizes. We are concerned with the costs of equipping cities of different size for profitable new industrial activities. The question of costs of industrial infrastructure, obviously, is only one among the operational issues posed in the previous paragraph. An integrative framework or rationale is needed to put the cost issue into the wider context, so that our findings will lead to useful conclusions and also serve as a valid guide for future planning and research.

Analytical Setting of the Present Study

A unifying framework for the cost study was suggested in the India Research Design, dovetailing analysis of the "minimum economic base" with analysis of agglomeration effects over a spectrum of city sizes. This approach starts with the following proposition:

> If unit costs of infrastructure fall substantially over some range of city sizes, and if other agglomerative forces have started to take effect, this range of city sizes may be looked upon as analogous to that section of the marginal productivity curve where output rises faster than input, and where investment should rationally be concentrated, at least up to the point at which the rates of change of total revenues and total costs are equated.

In elaborating this approach, we start with the two "ifs" in the above statement, which refer respectively to two connotations of the phrase "minimum economic base."

The first connotation of minimum economic base applies specifically to infrastructure costs. In effect, the research hypothesis asserts that until a city attains a minimum volume or scale of economic activities, its equipment in terms of power, water, transport, and other infrastructure facilities will not be large enough to take advantage of economies of scale and low unit costs. At some city size, presumably different for different sets of facilities and services, unit costs of infrastructure are expected to fall significantly.

In its more general connotation, minimum economic base suggests not only the scale of economic activities but also their variety, mutual support, and profitability, creating a conjunction or combination of conditions that foster industrial growth. These conditions, embodying moderate or substantial agglomeration effectis, may differ for different sets of industries. A comprehensive understanding of these conditions would involve study of the elements identified by Spiegelman as essential to any theory of agglomeration.* These agglomeration factors are:

1. Regional constraints on urban structure and growth (population, resource endowment, income levels and distribution)

2. Accessibility to adequate markets (influenced by transport distances and costs)

3. Internal economies of scale and the structure of industry markets

4. Economies of scale in the public sector

5. External economies or interindustry linkages in the private sector

6. Accessibility to adequate labor skills and supply (influenced by costs of migration and commuting to cities)

7. Communications and information transfer

8. Decision-making and the historical process

The quantitative focus of this study with respect to city size is on element 4, cost economies in public facilities and services for industry. As a basis for cost estimations, quantitative requirements of industry for infrastructure services must be determined. This is accomplished by establishing the needs of specific plants and summing these needs in appropriate proportions to determine the infrastructure requirements of sets of industries, for different size cities. Identifying industries which have promise for cities of given size obviously involves other agglomeration factors

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* Spiegelman, op. cit., p. 11.

in addition to infrastructure costs. Industrial interviews have contributed to assessment of these other factors, but, as detailed in Chapter IV, the focus of in-plant analysis is on infrastructure needs. The primary focus of research is therefore not on minimum economic bases or agglomeration effects in the wider sense, although findings on these elements are reported.

The point of this distinction is as follows. When scale economies of major physical and social facilities are summed, it may be found that reasonably low unit costs are reached at a size of city which is still substantially below that required to meet Spiegelman's other conditions for agglomeration. Since our inquiry is pointed to costs, we do not offer quantitative findings on this larger question. However, partial evidence and judgments have been sought. In particular, in establishing industry mixes oriented to different size cities, consideration has been given to patterns of interindustry support as well as to requisite labor skills and market accessibility. The final chapter presents conclusions on this and other agglomeration effects.

Urban Infrastructure Costs and Their Determinants

Massive amounts of literature discuss the exceedingly complex organism called the city and refer to extremely varying cost functions. In attempting to isolate certain developmental segments, the literature has advanced many terms and definitions as well as a wide array of notions, theories, and hypotheses. Unfortunately, the flow of valid, meaningful data on city size and cost relationships has been far less substantial, because of the complexity of both the city function and the cost function.

The approach of this project to analysis of urban costs is defined in this section. Relevant past research is first briefly reviewed. The scope of costs included in this study is then defined, followed by an indication of the magnitude of the main elements in infrastructure costs. Cost determinants are next identified qualitatively through description of urban subsystems and systems. The principal functional relationships and variables through which city size may influence unit costs are then identified. This establishes the structure of the analysis undertaken.

City Size as a Determinant of Infrastructure Costs

Past analyses of costs as related to city size have been mainly statistical. Of the few which separate public investment outlays from current expenditures, the study of Hansen for industrial communities in Belgium is most suggestive.[34] In communities of 1,000 to 50,000 population, Hansen found a pronounced tendency for per capita overhead capital outlays (social and economic) to increase with population size. This relationship, however, is not statistically significant for communities of over 6,000 population. In 38 communities of 6,000 to 50,000 population, per capita social overhead outlays are statistically associated with population density, degree of industrial employment, and change in housing density.

Economic overhead outlays--for roads, gas, electricity, water, sewerage, and other transport and commercial facilities--are associated with growth variables: percent population change, percent change in builtup land, and percent change in number of houses. Hansen found per capita overhead capital outlays, particularly for social overhead, substantially higher in the more industrialized communities.

The most comprehensive study of city expenditures in the United States is still that of Brazer, who concluded from multiple regression analyses that the apparent tendency of per capita municipal expenditures to increase with population size is not statistically significant.[29] Population density, median family income, intergovernmental revenue, type of city, and ratio of core city population to that of the standard metropolitan area are found to be significant variables. Sacks and Hellmuth found population size the most significant correlate with total municipal operating expenditures for cities in the Cleveland Metropolitan Area,* but population size was of relatively minor importance as an independent variable in the study by Carroll and Sacks of expenditures in New York State cities.[30]

In contrast, a recent study by Henderson concludes that population size is a significant variable.† Somewhat arbitrarily defining as metropolitan the 100 U.S. counties with largest 1957 population and as nonmetropolitan 2,980 remaining counties, Henderson finds per capita local expenditures positively associated with population size in metropolitan counties and negatively in nonmetropolitan counties--both statistically significant at the 1 percent level. The reduction of per capita expenditures with increased population size in nonmetropolitan counties is very marked. "This may be the result of decreasing costs in the provision of public services"‡ in nonmetropolitan counties, which have a mean population of about 21,200. Increases in per capita expenditure with population size in metropolitan counties are much smaller in absolute amounts. However, for the largest metropolitan county, with 1957 population over 5,000,000, the statistical relationship indicates annual per capita expenditure more than $50 above that of the smallest metropolitan county. 'The costs of very large size and congestion may be substantial."§

While Henderson's findings support the hypothesis of this study, the overall statistical evidence is inconclusive, as might be expected. City size is the resultant of complex growth forces. Cost and benefit influences are often indirect. The attempt of this project is to sort out

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* Seymour Sacks and William F. Hellmuth, Jr., Financing Government in a Metropolitan Area, The Free Press of Glencoe, Inc., New York, 1961, pp. 99-100.

† James M. Henderson, "Local Government Expenditures: A Social Welfare Analysis," The Review of Economics and Statistics, May 1968, Vol. I, No. 2, pp. 156-163.

‡ Op. cit., p. 160.

§ Op. cit., p. 161.

the major factors in these relationships, explicitly defining those analyzed here and those calling for separate research.

Scope of Costs Examined

Within the broad framework of physical and social infrastructure* required by industry in urban centers, the following cost categories are specifically included in this study: roads and railroad facilities, water, sewerage, power, telephones, housing and site development, education, hospitals, fire and police protection, refuse and garbage disposal, and municipal administration.

The broad criterion for defining the costs studied is direct involvement of public funds. In the case of housing, for instance, it is estimated that about 20 percent of the housing of industrial employees in the study region is financed by public grants and loans. This portion of the urban housing requirements of incremental industry is included in the cost estimates.

The following guidelines to the study of costs emerged from discussions with the project advisory committee:

1. Analyze costs in a technological sense, attempting to quantify the cost function for each facility in relation to scale, level of service, city size and density, and identifying other variables that influence the facility's costs.

2. Test the sensitivity of infrastructure requirements and costs to differences in industry mix and in standards or quality of facilities and services.

3. Without in any sense undertaking benefit-cost analyses of the urban facilities to be provided for incremental industry, base cost estimates on the general objective of attaining least cost configurations for essential facilities.

The study is confined to urban (city) infrastructure, and excludes costs of regional or intercity facilities. Infrastructure is taken to include the physical works and public services required for industry, but not the physical industrial plant itself or utility and other features within plant property limits. In terms of environmental control, the standards assumed for in-plant treatment of liquid wastes provide adequate protection against water pollution. Facilities for sewage disposal,

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* For an exhaustive recent examination of the concept and importance of infrastructure, see Clifton R. Wharton, Jr., "The Infrastructure for Agricultural Growth," in Herman M. Southworth and Bruce F. Johnston (Eds.), Agricultural Development and Economic Growth, Cornell University Press, Ithaca, N.Y., 1967, pp. 107-146.

although minimal, would provide control of domestic wastes generated by both industrial and residential areas. Air pollution is not considered.*

City size is related in a complex manner to other important factors which have indirect or less quantifiable cost implications. These include (1) secondary or multiplier effects of an industrial increment on a city's economic activities, leading to induced or indirect new infrastructure requirements; (2) related per capita income levels and distribution; (3) the personal and social costs of overcrowding and growth of urban slums; (4) costs of traffic congestion and its alleviation; and (5) potential technological changes over time.† Each of these major welfare and policy issues presents problems of theory and measurement too large to be studied with the resources available for this research. These dynamic factors in urban growth and decay are therefore reluctantly excluded from the scope of study.

Relative Cost Magnitudes: An Example

Comprehensive data on the relative weight of different facilities and services in total infrastructure costs are scarce. The most detailed breakdown of such costs examined for this study is the assessment by Dyckman and Isaacs of capital requirements for urban development and renewal in the United States.[33] Costs for renewal and maintenance of community capital are estimated for a metropolitan "Case City," with projected population growth from 300,000 to 370,000 in 12 years. Classifying as infrastructure the principal elements considered in this study, except housing, the overall Case City capital requirements are:‡

	Dollars in Millions
Residential	$ 897
Industry	679
Commerce	416
Infrastructure	343
Institutional	39
Total	$2,374

* See Ronald G. Ridker, Economic Costs of Air Pollution: Studies in Measurement, Frederick A. Praeger, Publishers, New York, 1967, 214 pp., for an approach to assessing physical and psychic effects of environmental factors.

† Interaction among these factors is comprehensively examined by Wilbur R. Thompson (reference 21). A powerful attempt to grip the dimensions of personal and social cost experienced in urban slums is made by Jerome Rothenberg (reference 147). Models for analysis of urban transport and location are provided by Lowdon Wingo, Jr. (reference 58) and Britton Harris (reference 35). Potential technological improvements are charted by Stanford Research Institute (reference 149).

‡ Reference 33, pp. 299-300.

The magnitude and percentages of individual infrastructure elements are shown in Table 1. These are of interest to the present study mainly in the fact that they pertain to existing cities. The values differ in the fact that they relate to cities already equipped with modern infrastructure systems, in not being pointed primarily to industrial requirements, and in including land acquisition costs. The high proportion for schools is noteworthy, and also the significant share for "open space." Water and sanitary systems together call for 14 percent, transport over 12 percent, and electric power and gas over 3 percent of investment costs, totalling about 30 percent for those elements which have major "collection and distribution" components.

Characteristics of Urban Costs

A consistent view of infrastructure costs can be built up in terms of urban spatial and functional subsystems, proceeding from local to city-wide systems.

Urban Subsystems. Commencing with the smallest describable system of infrastructure, we have what Kain[41] refers to as the structure distribution system--that set of utility elements located within multiple tenant structures. These vertical and horizontal type systems are provided at far less cost than for comparable facilities serving smaller structures at lower densities.

Second in order is the lot* distribution system, which includes the service laterals of water, sanitary sewer, telephone, and electric power, as well as walks and driveways. These features connect the structure's system with the neighborhood or industrial area distribution facilities which generally lie in public rights-of-way or common easements. Costs for the lot distribution system are a function of building setback (the less the distance between the structure and public right-of-way, the less the cost); of residential† lot design (the narrower the frontage, the greater the economies from dual use of lateral or access ways); and of density (the greater the multitenant use, the greater the economies).

Next, the on-site distribution system provides the lot with utility service and road and rail access. "On-site" in this sense means the site of a physically planned, contained, and integrated industrial area‡ or residential neighborhood. Kain has referred to this level of infrastructure as "intra-neighborhood distribution system." On-site facilities such

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* Synonymous with "plot" in the Indian context.

† For industrial plots, lot design will not achieve consistent economies where variation in utility demands is unique to individual industries.

‡ "Area" here is meant to be synonymous with district, estate, park, center. For purposes of this report, no distinction between industrial development types is intended.

Table 1

RELATIVE COSTS OF INFRASTRUCTURE ELEMENTS,
CASE CITY, U.S.
1958

Element	Estimated Cost* (thousand)	Share of Total Cost (percent)
Schools†	$118,505	34.5%
Open space	65,055	19.0
Transport	42,597	12.4
Health	27,148	7.9
Sanitary system	26,380	7.7
Water system‡	21,824	6.4
Electricity and gas‡	10,900	3.2
Community centers and libraries	10,024	2.9
City halls	8,375	2.4
Incinerator	4,900	1.4
Fire	3,568	1.0
Garage, warehouse	1,800	.5
Police	1,627	.5
Animal pound	650	.2
Total	$343,353	100.0%

* Including land acquisition costs.
† Public and private.
‡ Private.

Source: John W. Dyckman and Reginald R. Isaacs, Capital Requirements for Urban Development and Renewal, McGraw-Hill Book Company, Inc., New York, 1961, pp. 299-300.

as water wells and storage tanks, so-called package sewage treatment plants, power distribution substations, railroad transit sheds, and off-loading docks are included in on-site distribution system costs, so long as they essentially serve the industrial area or the neighborhood. On the other hand, fire stations, telephone exchanges, and other community-wide functions are not included in this system category (see subsequent section on public services system). The latter type of facility is located to serve a geographical area of activity, or often simply because of public demand and land availability; it is therefore only incidental that such a facility may be located on-site.

As size increases, the costs of single elements of the on-site distribution system may exhibit economies of scale. Aggregated system costs may also exhibit economies of scale, but such total costs are so greatly influenced by other factors that any size comparisons resulting therefrom must be carefully qualified. That is to say, apart from size, total costs are sensitive in varying degrees to street pattern and width, spur track layout, utility design, soil conditions, standard of service, block length, frontage to depth ratios, private automobile and public transit usage, and amount of land devoted to uses (including open space) other than the prime use. Even the significance of density as a determinant of costs is identifiable with other factors. Kain observed that ". . . . local design considerations reduce further the importance of net residential density as a determinant of the costs of urban services."

Next in the order of system scale and spatial relations is the off-site distribution system. Kain recognizes this level as "inter-neighborhood or trunk distribution systems," characterized by large connectors linking neighborhoods, industrial areas, and other urban uses to sources of supply, to treatment plants, and to transport terminals. To aid analyses, it is convenient to subcategorize the off-site distribution system costs thus: (1) facilities for intracity distribution and collection, including trunk and interceptor lines for sewage, water, drainage, high voltage transformer stations and power lines, telephone lines, citywide water and sewage treatement plants, arterial streets, railway spurs, and (2) intercity facilities serving as the "life lines" of the city--these include power grids, intercity highways and railways, and telephone and telegraph cables, but as noted, they are not covered in this study.

Intracity facilities can significantly affect city size and cost comparisons, either by economies of scale or cost sensitivity to proximity of location. The economy of common treatment plants or single large utility lines connecting several developments is self-evident; otherwise there would be little economic value of off-site facilities in the first place.* Except for terminal type facilities like treatment plants or power substations, the sensitivity of off-site costs to choice of location (distance

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* There are exceptions, of course--i.e., access to other city areas, to hinterlands, and to single source water or power supplies.

between on-site and existing off-site facilities) is far more difficult to generalize upon, at least in a long term cost sense.*

The last functional classification under urban subsystems is that of the public services system. For convenience, "public" refers to city, district, state, and national jurisdictions, even though the majority of urban services may be provided, or at least administered, at the local level. The public services systems considered in this study are health, education, police and fire protection, garbage and refuse disposal, and city administration.

Urban Systems: Influence of Urban Area, Form, and Physical Growth Patterns. Here the concern is with geometric form and its attendant infrastructure costs, which shape urban growth patterns. Given a purpose (economic livelihood), a population and activity base, and criteria for the physical space to house the population and conduct the activity, two basic choices prevail: (1) the development of a new town or a new community spatially separated from existing cities; and (2) the expansion of an existing city and its urban infrastructure to accommodate the new growth. There is a whole set of economic and political criteria unique to the first alternative. Only the second alternative--expansion--is considered in this study, even though in developing countries, expansion of urban facilities and services in existing cities is often not unlike new communities "starting from nothing"--for example, when the existing city has systems or services that are minimal.

In the expansion process, one method is that of infilling of existing partially built-up areas. As long as this infilling does not violate the city's master plan objectives and as long as sufficient amounts of land are available, the concept would apply to cities whether they be concentric, radial, or lineal in form.

Wheaton and Schussheim,[55] in their 1955 study of three cities in Massachusetts (one of 5,000 population size class, one of 20,000, and the third at 80,000), showed that for a given requirement of 500 dwelling units, it was generally less costly to develop in "scattered growth areas" than in "concentrated areas." Their study included the costs of schools, streets, sewers, water, and fire protection. The study illustrates

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* Further complicating location choices is the introduction of private (versus public) costs over time of the industrial or other user. As an example, say that planning has minimized the costs to install, operate, and maintain power and water service over a relatively short distance and an access roadway over a comparatively long distance. Yet, the nature of several industrial tenants using the facilities is such that product travel time and transport mode decision are most critical, causing long term diseconomies to occur in what might otherwise have been a minimum cost situation. However, this sort of refinement is disregarded in this study, considering the inherent heterogeneity of the industrial development.

the low-cost theory of infilling which is sound where relatively small increments of demand are placed upon existing utility or access systems, and especially where initial designs allowed for full development of all neighborhoods. This would be true for both line networks and nodal facilities. For terminal facilities and the municipal services system, however, costs would generally be the same whether growth by infilling was scattered or clustered.

For reasons of scarcity of available city lands, or land use zoning, or "identity" of development, or economies of centralized administrative control, clustering or concentrated growth may prevail. As cluster or concentrated types of development increase in size, their on-site costs generally exhibit economies of scale. This is due to unity of design and more efficient use of capacity (exceeding minimum working standards of size, i.e., diameter of pipe, width of road). Similarly, economies might be shown for off-site connector facilities. However, locational factors having to do with proximity of the site to existing facilities or the number of connection alternates available would substantially diffuse any apparent economies of scale.*

In expanding by radial or lineal patterns, as opposed to infilling, the larger the urban spread, the greater the cost of lineal off-site linkages of facilities. This point can be exemplified by the simple geometry of the circle--as distance increases from the center, the circumferential (city limit) length will vary directly with the distance, but the circumferential area added increases by the square of the distance. Translating geometry to cost, the demand placed upon existing city systems by large new developed acreages may become the critical cost factor. Density of development is one determinant of these costs. For any given density, however, costs are a function of the absolute size of the urban area, which determines the load or demand on system connectors as well as their length.

Geographic Environment. Costs of infrastructure can vary from one location to another because of natural features--topography, geology, including soil conditions, hydrology, climate, and geography. One criterion for selection of the area of field study in India was that it should not

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* A rather obvious example of this locational effect is contained in the Wheaton and Schussheim study: one of the concentrated type alternatives was less costly than another of similar type. The reasons for this were that the first alternative was closer to a water main, was close to an existing sewage interceptor, was near a school (having excess capacity), was within one mile of neighborhood shopping and two miles of regional shopping, and was nearer to an intercity highway. Comparative cost results, of course, are obvious in this case, but case examples of specific conditions in specific environments do not suggest very forceful or meaningful generalizations.

have significant variation in these physical phenomena. In the more general case, however, these considerations could be vital to meaningful city-by-city cost comparisons.

Analysis of Urban Cost Variables

Several pervasive factors run through the above delineation of cost characteristics. Those which can be related to city size and are explicitly examined in this study include: economies of scale in individual facilities and their components; level of development of existing facilities; city area and form; population density; and types and standards of facilities required for industrial activity of different types. Price variables such as costs of land, capital, construction labor, and materials are also subject to influence by city size and are explicitly examined.

Scale Functions. The many facilities and services which comprise a city's infrastructure include some components with constant unit costs as a function of scale, others with varying degrees of decreasing costs, and others with increasing costs.* Total infrastructure cost reflects the summation of each of these cost functions over the relevant range of urban size. Scale effects therefore receive major attention, for individual facilities and components in Chapter III, and for facilities as a whole in Chapter V.

Level of Development of Existing Facilities. Since the concern of the study is with incremental costs of industrial infrastructure in existing cities as contrasted to the founding of new towns, existing levels of infrastructure development in cities of different size must be examined for their possible bearing on unit costs. Questions to be answered are:

1. Does the existence of large facilities in large cities result in lower incremental costs than can be realized by smaller facilities in small cities?

2. Do large (small) cities have more "unutilized" facilities or "excess" capacity available to industrial entrants than small (large) cities?

3. Or are scale economies principally realized through the absolute size of industrial growth increments, enabling larger increases in facility size in large cities?

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* L. Bruni, "Internal Economies of Scale with a Given Technique," The Journal of Industrial Economics, Vol. XII, No. 3, July 1964, pp. 175-190, summarizes technical and economic factors that give rise to economies of scale, and presents a general analytical model for evaluating scale effects in different types of facility or plant.

In economic terms, questions 1 and 3 relate to the feasible shape of the long-run cost curve, whereas question 2 refers to the city's position or use level on a short-run cost curve. It may appear that question 2 is irrelevant from the standpoint of planning public infrastructure investment. A discussion of the nature of urban facilities is in order to indicate the relevance of each question. Questions 1 and 3 ask: is the long-run cost curve made up by successive small enlargements to existing plant, each at lower unit costs, or does it represent the envelope of essentially discrete short-run cost curves, each for a facility of different capacity? The answer depends on the technology of each facility. However, a study of the specific facilities encompassed in urban infrastructure suggests the following clarification. Individual facility components (e.g., ground water well, 12-in. water main, 36-in. sewer trunk, overhead water storage tank, 33/11 KV transformer of 6,000 kva capacity) are fixed in size and typically not open to enlargement of capacity, except in the very narrow range denoted by overload conditions. The scale function or long-run planning curve for a specific component is therefore always a hypothetical, ex ante curve, not a realistic expansion path over time, except by replacement. This is, of course, the definition of a long-run curve when viewed as a planning curve: no factors are fixed. In reality, urban facilities are made up of several separate components (a water system may consist of wells, pumping station, storage tanks, interneighborhood connector mains, on-site networks, as well as lot and structure distribution lines). It is not necessary--in fact, in developing systems it is exceptional--that capacity of each of these components should be perfectly in balance at any point in time; the effective size or capacity of the facility is determined by the maximum output or throughput or flow of the bottleneck component. Substantial excess or unutilized capacity may exist in other fixed components. By size of facility, then, "we refer to the existence of different short-run cost curves resulting from different collections of fixed factors."* Adjustment in the capacity of such a facility is typically made by successive additions to the bottleneck components. Capacity increase is thus not a pure scale increase, but a change in proportion among the principal components. The expansion path represents shifts in the combinations of short-run cost curves of different components. For a facility as a whole, therefore, question 1 merges into question 2 and the theoretical distinction between long-run and short-run curves becomes less sharp.

It can be shown that temporarily "unbalanced" capacities among facility components may represent optimal long-run planning, in which case successive savings in incremental costs in part represent spreading the costs of underutilized fixed components over larger output, the typical short-run cost case.† This applies also to the overhead costs of administrative staff and maintenance crews, who are required in a minimum mix of skills

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* Earl O. Heady, Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., New York, 1952, p. 365.

† See Marcel Boiteux, "Peak-Load Pricing," in James R. Nelson (Ed.), Marginal Cost Pricing in Practice, Prentice-Hall, Inc., 1964, p. 72, for an example of "deliberate overequipment" and pricing based on development cost.

for a given facility but may be substantially underutilized until the physical scale of components reaches a certain level. For a cross section of cities of different size at a point in time, the degree of excess capacity in urban infrastructure is therefore not necessarily irrelevant to investment decisions. While sunk costs may be disregarded, the existence of different levels and composition of infrastructure can result in lower incremental facility or system costs for certain cities. Verification of this possibility is a point of fact, for which this study provides a test as related to city size.

The hypothesis that incremental infrastructure costs in small cities are higher than in medium or large cities suggests, at least by implication, that in the latter instances the developed supply of infrastructure achieved or inherited at a point in time is more complete or adequate than in smaller centers. Unused capacity due to indivisible or "lumpy" components would hypothetically be available to an incremental industry mix at marginal or development costs.* With increase in size and variety of city facilities, opportunities may also increase for sharing joint economies in the use or establishment of capacity.

Commonplace examples of technical indivisibilities are off-site connectors: roads, water mains, sewer trunks, and power lines. A minimum length must be built, and hence a threshold cost incurred, simply to join related parts of the city. The capacity of connectors, however, is related to their width (or diameter) and design.† Standard pipe diameters illustrate technical "indivisibilities." Minimum diameter requirements of mains may be exceeded, however, if cost savings are anticipated through installation of a larger pipe now instead of re-excavation and laying of a second pipe later. This exemplifies a lumpy component in the cost sense, with excess capacity. One instance of arbitrage (trading present for future costs) and lumpy fixed costs in power distribution is provided, in the India study region, by the new grid substation at Kanpur. Bays and feeders for 15 33/11 kv transformers have been built, but some 10 transformers are yet to be installed pending anticipated load increases.

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* For a strict comparison, use by incremental industry of spare capacity should pay its way. In theory, this could be accounted for by projecting the number of years in which normal growth of the city's demands would catch up with the appropriated share of supply, and discounting the cost of its replacement as of that date back to the time the facility was assigned to industrial entrants. This procedure was considered but in practice did not prove necessary for the cities examined.

† Lowdon Wingo points out that physical capacity is rarely a simple function of the scale of the facility, and that scalar capacity measures probably always carry implicit assumptions about service quality. In addition to the number and width of traffic lanes, for example, the volume, speed, peak demands, and other characteristics of traffic must be taken into account in estimating highway capacity.

Unused capacities and locations of existing community facilities are given major attention by Isard and Coughlin in their detailed pilot analysis of the impact of industry on municipal finances.[39] As a basis for estimating costs of incremental infrastructure, Isard and Coughlin establish realistic but hypothetical examples of existing capacities of main roads, feeder and local roads, sewerage plant, sanitary and storm sewers, and schools. This permits concrete application of their methodology for estimating costs of neighborhood development at three residential densities, for three sizes of industrial increment, at "high" and "low" service levels. The procedure provides no grip, however, on variations in existing capital stock and unused capacity as a function of city size.

Our approach to identifying the effects of city size on unused capacity and related variables is through the following steps.

1. In selecting cities of different size for initial field study, choose cities with similar economic and physical characteristics, to reduce the influence of variables extraneous to city size. The criteria and cluster analysis used to select the sample of 18 cities are described in the next section of this chapter.

2. While obtaining information on industrial needs and costs in the 18 selected cities, build up an inventory of their existing infrastructure, with details on facility size and on supply-demand relationships. The City Inventory and capacity use levels are examined in Chapter V.

3. Make concrete estimates of incremental costs for new industry in a subsample of test cities, representative of their population size among the 18 cities with respect to existing facility capacity and use levels. The procedure for selecting five test cities for incremental cost estimation is explained in Chapter V.

4. In selecting industrial and residential sites as a basis for cost estimation, adopt consistent criteria for site selection and for tie-ins with existing facilities. These are detailed in Chapter V.

5. In incremental cost statements, segregate costs required to augment or connect with existing facilities, to compare this factor among the five test cities. Such costs are identified in the "off-site" cost category in relevant sections of the report.

6. In applying this procedure, interpret specific local features of the five test cities which might affect the general validity of results.

City Area and Form. The points just noted are pertinent also to the cost effects of size of urban area, which influences the length of off-site connectors and their load. Analysis of off-site costs for the five test cities reflects these factors.

Criteria applied in site selection include the requirement that land costs for the chosen site should be reasonable in comparison with the costs of other candidate sites in the same city. The intent is not to put the five test cities on an equal footing with regard to distance of site from the central business district or any other land cost determinant attributable to city size. The intent, rather, is to assure that in each city, the site is relatively no more nor less advantaged than in the other test cities with regard to costs of access. Off-site cost estimates thereby become pertinent as a partial indicator of the effects of city area and distance.*

For a given density of development, the size or extent of city area influences trade-offs between scale economies in nodal or terminal facilities, on the one hand, and in lineal distribution facilities on the other. Classification of incremental costs among nodal, lineal, and areal components in Chapter V is intended to assist in analyzing the relative effects of scale and distance on costs.

Population Density. Density is a critical element in the human costs of slum life and in urban congestion costs. As already observed, density also has significant influence on direct infrastructure costs. Although nonquantifiable and indirect social costs are not considered in this study, their importance as well as the direct cost effects of density call for particular attention to the assumptions of the study with regard to residential density.

Density together with other design factors and construction standards enters directly into trade-off calculations between building costs and the costs of structure, lot, and on-site infrastructure facilities. Variation in density also influences off-site and city service system costs. Possible combinations of these variables are very numerous. Ludlow's conclusion is still perhaps the most valid generalization that can be made: "[I]t appears that the costs of providing public service to a residential

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* The principal qualification, discussed in Chapters V and VI, results from inability to give full treatment to congestion costs. An an approach to this and related problems, it was pointed out by Lowdon Wingo at the advisory committee meeting that sites of more or less equal land costs, or at equivalent points on the urban rent gradient, could be found in each test city. In a land market characterized by reasonably good information, such costs would be inversely related to real costs of access, including congestion. As seen later, sharp land cost variations attributable to local factors evidently unrelated to the size of the test cities precluded use of this procedure, quite apart from the formidable implication of obtaining and interpreting adequate land price information on a comparable basis for differenc cities.

area are greatest at very high and at very low densities. At some intermediate point in the middle density ranges, public service costs are lowest. Special studies are needed in each city to determine the density ranges which will be conducive to lowest governmental costs in any specific locality."*

Stone has performed extensive studies of this type for alternative town configurations in England and is completing a major schematic study which incorporates variations in city size, density, shape, road form, and land use.[53]† Jones has analyzed density trade-offs for schematic neighborhood layouts and city transport systems using cost data for Ciudad Guayana, Venezuela.[40] International variations in urban densities and costs are so substantial, however, that much further comparative analysis is required to produce generally applicable guidelines on costs as a function of density, either at the neighborhood level or for citywide systems.

Corporate and developed area densities for the 18 cities in our field study are reported in Chapter V and applied as a screening criterion in selecting five cities for incremental cost estimation. In cost estimation, gross residential density is held constant among the five test cities in order to analyze the effects of city size alone. This permits use of comparable per acre cost data for such elements as site development and on-site roads, water, sewerage, and power distribution networks. Micro-level cost optimization for different neighborhood densities, which would be a prerequisite to assessing the cost effects of simultaneous variation in both city size and density, is not undertaken.

Types of Industry. Relationships between industry types, city size, and infrastructure requirements are the focus of Chapter IV and are introduced as a principal variable in the second test of the research hypothesis.

Facility Standards. Standards for services directly required by industry (e.g., power, water, and transport) are based on intercompany comparisons and evidence of efficient current industrial practice and trends in the field region, as detailed in Chapter IV.

Standards of residential and other social infrastructure for industrial employees and their families are kept constant in the five-city cost estimates. Attainment of equivalent water supply levels for civic uses in the largest two test cities requires an increase in per capita availability. Achievement of equivalent space standards for parks and other community facilities in the largest test city, at constant gross residential density, requires a shift from two story to four story housing. These and

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* Reference 53, p. 147.

† Also see forthcoming study directed by P. A. Stone and sponsored by National Institute of Economic and Social Research, London.

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other social service standards are defined in Chapter V, and their effects on costs are analyzed in cost tabulations in that chapter.

Price Variables. Analytical treatment of the costs of construction labor and materials, land, and capital is defined at appropriate points in the report.

Selection of Region and Cities for Study

Selection of the region for field study was governed by considerations of methodology, of the study's general relevance, and of possible direct usefulness of the results. The Indo-Gangetic plain region in the states of Punjab, Haryana, and Uttar Pradesh offered several advantages in this regard:

1. The region is virtually a homogeneous plain. No other region of comparable population and area offers such a challenge for study of urban growth patterns under relatively uniform spatial and topographic conditions.

2. Industrialization and urbanization have proceeded rapidly in parts of the region during the past two decades, providing the widest contemporary evidence in India on interrelations between industrial and urban development in the size range of cities under study. Particularly in medium and small towns in the western part of the region, much of the recent development of manufactures is closely linked to progress in agriculture. This is of particular relevance in the context of intensive agricultural development programs now under way in several districts in various parts of the region. In the central and eastern parts of the region, road links and power grids established under the Second and Third Five-Year Plans offer new regional support to industry. Study of urban industrial infrastructure requirements is therefore timely.

3. The region's number and variety of cities permit study of a sample of cities which differ widely in size but have similarities that contribute to the research objective.

In contrast, most other regions in India are demarcated by geography into smaller, distinctive subregions. The number of cities of different size but with similar topographic and structural conditions is much smaller, reducing the comparability and generality of research results from such subregions. Therefore, it was believed that use of a relatively uniform region would give wider relevance to the data and research techniques developed and would facilitate subsequent analysis and planning in other regions and cities.

A starting point for analyzing the role of urban centers in the selected region is provided by contrasts in population and urbanization

trends between Uttar Pradesh and Punjab, prior to separation of Haryana. The 1961 census population of Uttar Pradesh, 73,746,401, represented an increase of 16.7 percent over 1951, resulting in a population density of 648 persons per square mile (Table 2). The 1961 population of Punjab, 20,306,812, an increase of 25.9 percent over 1951, represented a density of 429 persons per square mile. The urban* population of Punjab, however, increased by 35.9 percent from 1951 to 1961, compared to an increase of only 9.7 percent in the urban population of Uttar Pradesh. The respective urban shares of population in 1961 were 20.1 percent for Punjab and 12.9 percent for Uttar Pradesh.

With respect to the largest cities, the pattern of urbanization is reversed (Table 3). Punjab as of 1961 had no city over 500,000 while Uttar Pradesh had three. Kanpur, the largest city of Uttar Pradesh, presents the picture of a primate city which has outstripped urban growth in its hinterland, except for the nearby state capital, Lucknow.

The rapid growth of urban population in Punjab between 1951 and 1961 was well distributed among cities of different size. Fifteen of the state's urban centers over 20,000, or 31 percent of the total, increased in population by more than 40 percent in the decade. Of these, five were in the 50,000-100,000 size category and one, Ludhiana, in the 100,000-250,000 category. Only 13 percent of the cities over 20,000 in Uttar Pradesh increased in population by more than 40 percent during the 1951-61 decade. Of these, all but two were in the 20,000-50,000 category.

In order to study relationships between urban growth, industry, and other variables, a cluster analysis was carried out for the 134 cities in the region having a 1961 population of over 20,000 persons.† The analysis served as a basis for selection of sample cities for field study.

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* Urban areas, as defined in the 1961 Census of India, include municipalities, notified areas, cantonments, and all other places that satisfy the following three conditions: population over 5,000; at least three-fourths of the population dependent on nonagricultural livelihood; and density of population over 1,000 persons per square mile. Government of India, Census of India 1961, Vol. XV, Uttar Pradesh, Part IIA, General Population Tables, p. 15. In the Census of India, an urban area is considered a town, and towns over 100,000 are considered cities. In this report, we use the word "city" more generally, including Indian towns of 20,000 and over.

† We are particularly indebted to Professor Brian Berry for suggesting, at the advisory committee meeting, a cluster analysis of cities in the region. The analysis was carried out by Geoffrey H. Ball and James W. Eusebio, of SRI. Four computer runs on selected variables were carried out using the ISODATA technique developed by Geoffrey H. Ball and David J. Hall. The form of analysis finally adopted was performed with the clustering algorithm developed at SRI by Richard K. Singleton and William Kautz. See Geoffrey H. Ball, "Data Analysis in the Social Sciences - What About the Details?' in American Federation of Information Processing Societies, Joint Computer Conference Fall 1965, Vol. 27, Part I, Spartan Books, Washington, D.C., 1965, pp. 533-559.

Table 2

URBAN POPULATION AND AREA
PUNJAB AND UTTAR PRADESH
1961

	Punjab*	Uttar Pradesh
Population		
Urban	4,088,595	9,479,895
Total	20,306,812	73,746,401
Percent urban	20.1%	12.9%
Area (sq mi)		
Urban	432	957
Total	47,305	113,878
Population per Square Mile		
Urban	9,476	9,903
Total	429	648

* Includes Haryana.

Source: Government of India, Census of India 1961, Punjab, Vol. XIII, and Uttar Pradesh, Vol. XV.

Table 3

URBAN POPULATION INCREASE BY CITY SIZE CLASS, 1951-1961
PUNJAB AND UTTAR PRADESH

Percentage of Population Increase	Total	City Size Class: 500,000 & Over	250,000-499,999	100,000-249,999	50,000-99,999	20,000-49,999
PUNJAB*						
110 - 120%	1				1	
100 - 109	2					2
90 - 99	1					1
80 - 89	1					1
70 - 79	1				1	
60 - 69	3				2	1
50 - 59	3			1		2
40 - 49	3				1	2
30 - 39	9		1			8
20 - 29	11			1	3	7
10 - 19	7		1	1	3	2
0 - 9	5				1	4
-10 - -1	2	—	—	—	1	1
Total	49	--	2	3	13	31
UTTAR PRADESH						
90 - 99%	1					1
60 - 69	1				1	
50 - 59	2				1	1
40 - 49	7					7
30 - 39	18	3	2	3	1	9
20 - 29	17		2	1	3	11
10 - 19	30			4	7	19
0 - 9	9	—	—	2	3	4
Total	85	3	4	10	16	52

* Includes Haryana.

Source: Government of India, Census of India 1961, Punjab, Vol. XIII, and Uttar Pradesh, Vol. XV.

The object of the cluster-seeking technique is to partition, or sort, the set of 134 cities into subsets or clusters, each cluster containing cities that are as much alike as possible with respect to the variables analyzed. Eighteen variables were analyzed in the computer procedure that was finally used. For purposes of the analysis, each city was in effect an individual "collection of measurements" on the selected variables. The essence of the clustering procedure was to minimize the sum of the squared distances of each city, on each variable, from its nearest cluster center. A cluster "center" was visualized, in multidimensional space, as the vector of mean values on all variables for the cities which formed the cluster. When separated and regrouped through an iterative technique, the clusters of cities tended to become increasingly compact, representing collections of measurements that were closer and closer to one another. Correspondingly, distances between cluster centers became increasingly great.

Ten clusters of cities took shape in the final computer analysis. The mean values on each variable are shown on Table 4 for all cities combined and for each of the ten clusters.* The table also presents lists of the cities forming each cluster. Three large clusters were formed. In order of manufacturing importance they had 22 cities, 44 cities, and 40 cities, respectively. The remaining seven clusters had one to seven cities.

In the analysis portrayed on Table 4, clear and consistent correlation between the percentage of workers in manufacturing, rate of urban population growth, and percentage of district urbanization is observed for the largest three clusters. Cluster 1 has high mean values on each of these variables, Cluster 2 is virtually at the all-city mean, and Cluster 3 is far below the all-city mean on each of these variables. In modified form, the literacy rate is also closely associated with the percentage of manufacturing employment. Clusters 1 and 2 have literacy rates above the all-city mean, while Cluster 3 is next lowest of all clusters in the mean value for literacy.

No associations emerge, on the other hand, with regard to urban density. Mean values for corporate area per capita are virtually the same for the largest three clusters and show no distinctive variation except

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* The mean values shown on Table 4 are "scaled" values, not the actual means of the universe of 134 cities or the ten clusters. Scaling is performed prior to the formation of clusters to neutralize (or adjust) the weights of the variables; otherwise, large numerical values, due simply to the units of measurement of the different variables, would distort the calculation of sum-of-squares-distances. In the form on Table 4, the mean values can be used only for comparison among clusters on each variable, not for further numerical applications.

Table 4

URBAN CLUSTER CHARACTERISTICS AND CLUSTERS
PUNJAB, HARYANA, AND UTTAR PRADESH
1961

Cluster Means (Scaled) for Eighteen Urban Cu

Cluster Serial Number	Number of Cities in Cluster	% of Workers in Manufacturing 1961	% Growth of Population 1951-61	% Urban To District Population 1961	% Literate 1961	Corporate Area Per Capita 1961	% of Workers in Construction 1961	% of Workers in Transportation 1961	Food, Beverages & Tobacco Products	Textiles	Apparel and Misc Textiles
										Percentage of	
All Cities	134	1.57	1.42	1 91	4.55	1.13	0.90	1.45	2 37	0 88	2 19
										Three Largest Clusters*	
1	22	2.47	2.15	2.70	4.80	1.50	.76	1 15	1.73	2.28	1.87
2	44	1.47	1.38	2.02	4.70	1.16	.87	1.46	3.27	.77	1.81
3	40	1.03	.93	1 07	4.04	1.42	.74	1.10	2.30	.53	3 26
										Remaining Clusters*	
4	3	2.93	1.87	3.06	4.04	1.08	.51	1 12	1.29	.18	1 47
5	6	1.96	.98	2 27	3 55	.59	.63	1.44	1 66	35	1.25
6	7	1.95	2.49	2.04	5.28	1.05	.82	1.70	1.63	.82	1.08
7	3	1.67	1.46	2 09	6.13	1 74	5.58	.86	2.16	14	1.21
8	2	1.21	52	2 16	6.25	1.68	1.12	1.97	1 74	29	2.32
9	6	1.17	1.52	2.44	4.75	1 75	.80	2.29	1.23	.16	2.13
10	1	1.03	1.73	2 63	5.59	4 36	.91	9 67	1.28	2.41	1.72
F-ratio		5.66	4.52	8.17	5 13	1.78	14.31	19.81	13.01	10.96	16.32

Cities in Each Cluster, By State† and City

City Size Class (1961)	Cluster 1			Cluster 2			Cluster 3		Cluster 4		C
	Punjab	Haryana	Uttar Pradesh	Punjab	Haryana	Uttar Pradesh	Uttar Pradesh		Uttar Pradesh	Haryana	Utt
500,000 and over			Kanpur						Agra		
250,000-500,000	Amritsar Jullundur		Varanasi Meerut			Bareilly					
100,000-250,000	Ludhiana			Patiala	Ambala	Saharanpur Dehra Dun Rampur Mirzapur	Mathura Shahjehanpur				Mor Ali
50,000-100,000		Jagadhri Hissar Bhiwani	Ghaziabad Hapur	Ferozepur Bhatinda	Rohtak Karnal Panipat	Muzaffarnagar Hardwar Pilibhit	Farrukhabad-Fatehgarh Faizabad Etawah Jaunpur Budaun Bahraich Sitapur		Firozabad		Aur Sam Had
20,000-50,000	Abohar Jagraon Khanna Tarn Taran Malout	Hansi Sirsa	Modinagar Baraut Mawana Bhadohi	Moga Malerkotla Phagwara Kotkapura Fazilka Muktsar Nabha Kapurthala Sangrur Rajpura Faridkot Jind Mansa Sunam Barnala	Sonepat Kaithal	Maunath Bhanjan Roorkee Haldwani-Kathgodam Barabanki Azamgarh Lakhimpur Deoband Rae Bareli Deoria Kairana Shamli Kashipur	Balandshahr Gonda Khurja Basti Ballia Banda Kasganj Ghazipur Hardoi Najibabad Bijnor Mainpuri Tanda Balrampur Nagina Unnao	Orai Shahabad Fatehpur Sikandrabad Sultanpur Vrindaban Mahoba Etah Kannauj Tilhar Konch Shikohabad Sahaswan Chandpur Miratpur		Karnaul	Chs

* Ranked by percentage of workers in manufacturing.
† Haryana cities as of 1966.

Source: Govt. of India, Census of India, 1961, Volume XIII, Punjab, and Volume XV, Uttar Pradesh.

Table 4

: CHARACTERISTICS AND CLUSTERS
ARYANA, AND UTTAR PRADESH
1961

r Means (Scaled) for Eighteen Urban Characteristics

	Percentage of Male Persons Employed in Urban Manufacturing (1961) in the District in									
Food, Beverages & Tobacco Products	Textiles	Apparel and Misc Textiles	Wood and Wood Products	Leather and Leather Products	Chemicals, Rubber, Paper & Their Products	Non-Metallic Mineral Products	Basic Metals and Metal Products	Machinery	Transport Equipment	Printing, Publishing, & Miscellaneous
2.37	0 88	2 19	2.31	1 80	0 65	0 98	1 11	0 61	1 14	2 39
	Three Largest Clusters*									
1.73	2.28	1.87	1 51	1 31	63	50	1 23	69	98	2 54
3 27	.77	1 81	2.52	1 70	58	1.02	98	17	1 04	1.96
2.30	53	3 26	3.08	2 21	12	1 00	.70	26	1 03	2 60
	Remaining Clusters*									
1.29	18	1.47	1 16	5 14	.27	6 57	69	14	43	1 95
1.66	35	1 25	1 48	99	.21	57	5.16	17	.53	1 79
1.63	82	1.08	1 81	1 95	.91	.71	1.24	1 13	75	2 41
2.16	14	1 21	1 99	.99	6.11	43	1 07	45	55	3 06
1 74	29	2.12	2.46	1.50	23	.54	56	27	75	7 63
1 23	.16	2.13	1 77	1.34	.51	.70	.17	16	5 00	2 17
1.28	2 11	1.72	1 24	68	.62	59	1 26	38	1.04	3 88
13.01	10 96	16.32	9 39	9 17	32 53	14.11	62 71	67 99	36 27	16 01

ies in Each Cluster, By State† and City Size Class

er 4	Cluster 1		Cluster 5	Cluster 6		Cluster 7	Cluster 8		Cluster 9	Cluster 10
adesh	Uttar Pradesh	Haryana	Uttar Pradesh	Punjab	Haryana	Punjab	Uttar Pradesh	Punjab	Uttar Pradesh	Uttar Pradesh
	Agra								Lucknow	
							Allahabad			
			Moradabad Aligarh						Gorakhpur Jhansi	
Fatehgarh	Firozabad		Amroha Sambhal Hathras	Pathankot Batala	Faridabad	Chandigarh Hoshiarpur				
Orai Shahabad Fatehpur Sikandrabad Sultanpur Vrindaban Mahoba Etah Kannauj Tilhar Konch Shikohabad Sahaswan Chandpur Kiratpur		Narnaul	Chandausi	Gurdaspur	Gurgaon Rewari Palwal	Nangal		Simla	Lalitpur Bela- Pratapgarh Mauranipur	Mughalsarai

for Clusters 5 and 10.* This is a disappointing result from the standpoint of evaluating density as a factor in urban infrastructure costs. The fact that urban density as measured by corporate area is not related to the other variables being analyzed no doubt reflects the wide and largely random divergence in areas classified as "corporate." Some improvement is achieved in Chapter V by using "developed" acres per capita as a second measure of density for the 18 cities covered in the field survey.

A moderate degree of correlation between city size and level of manufacturing is indicated by the leftward-sloping diagonal array of cities in the first three clusters at the bottom of Table 4.† Cluster 1, with the highest level of manufacturing employment among the three large clusters, has the highest share of cities above 250,000 population and lowest share of cities below 50,000. Cities of 50,000-100,000 are also well represented in Cluster 1, however, as they are in Cluster 2, along with cities of 100,000-250,000. Cluster 3, lowest in manufactures, is conspicuously confined to Uttar Pradesh, with a high share of cities below 50,000 population, many of which are district administrative headquarters.

The distribution of manufacturing employment among industry groups shows substantial contrasts between Clusters 1 and 2, and sharper contrasts with Cluster 3.‡ Cluster 1 has a high mean percentage of employment in textiles; is somewhat above the all-city mean in basic metals and metal products, machinery, printing and publishing, and miscellaneous manufactures; and is low in food, beverages, and tobacco products, wood and wood

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* The low F-ratio for this variable on Table 4 confirms the lack of significant variation among most clusters with respect to density. For each variable, the F-ratio represents the ratio of the sum-of-squares distance between cluster means to the sum-of-squares distance within clusters, and is thus a measure of the extent to which, for each variable, the clusters represent real differences and similarities in the underlying data. It will be noticed, however, that F-ratios on the right side of the table, for percentage distributions of manufacturing workers, are distinctly higher than for the more aggregative variables on the left of the table. In part, this simply reflects the narrower data set encompassed in a manufacturing category and the effect of percentage variations among categories, summing horizontally to 100 percent. In part, it reflects also the substantial degree of manufacturing specialization in a few cities, observed for Clusters 4 to 10.

† Size of city was expressly excluded as a variable shaping the formation of clusters, because the standard deviation of city sizes is so high that this variable would tend to dominate clustering. The size distribution on Table 4 was made after clusters were formed. The size classes of Table 4 and Figure 1 reflect "Town Group" population in the case of cities for which this information is given in the Census of India 1961.

‡ In order to include composition of manufactures as part of the cluster analysis, it was necessary to use data on urban manufacturing employment by district, rather than for each city individually. In interpreting Table 4, adjustments must be made for cities which are found in a single cluster mainly because they belong to the same district.

products, leather and leather products, and nonmetallic mineral products. For Cluster 2, the high mean percentage in food, beverages, and tobacco products and wood and wood products is to be noted; its distribution of manufacturing employment in other categories is for the most part slightly below the all-city mean. Cluster 3, the least "industrialized," is marked by high mean percentages in apparel and miscellaneous textiles, wood and wood products, and leather and leather products; its mean values in metals and machinery are notably low.

The seven smaller clusters are distinguished principally by sharp concentrations of manufacturing employment in particular industry groups. Clusters 4, 5, and 6 are well above the all-city mean in percentage of total workers in manufacturing. Cluster 4 is shaped essentially by the leather manufactures of Agra and glass products of Firozabad. Cluster 5 is determined principally by the traditional metal manufactures of Moradabad and Aligarh, which are of long standing. This cluster has by far the lowest mean values for rate of literacy and corporate area per capita, as well as low population growth. Cluster 6, dominated by the machinery manufacturing of Faridabad and Batala, has significantly high mean values for literacy and population growth.*

We conclude from the cluster analysis that there are important associations between manufacturing employment, urban population growth, district urbanization, and literacy rates; that the percentage of workers employed in manufacturing tends to be positively associated with size of city; and that relationships between the composition of industries and levels of manufacturing employment are discernible in cities of different size. When refined data on appropriate variables can be developed, cluster-seeking techniques evidently have much promise for the analysis of industrial location in an urban and regional context. Relationships between size of city and types of industries are pursued in Chapter IV through use of a simpler technique, the location quotient, geared to the form of data now available.

Results of the cluster analysis were applied directly in selecting the sample of 18 cities for detailed field study. The criteria adopted for the selection process are as follows:

1. Evidence of manufacturing growth propensity

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* Clusters 7 to 10 may be described as follows, having regard to the F-ratios which characterize each cluster. Cluster 7 is an artificial one-district cluster dominated by the fertilizer industry of Nangal. Cluster 8 combines the high literacy rate and printing and publishing industries of Allahabad and Simla. Cluster 9 reflects high employment in transport equipment manufacture as well as the high percentage of transportation workers in cities such as Lucknow, Gorakhpur, and Jhansi. The rail junction of Mughal Sarai stands alone in Cluster 10 for its exceptionally high percentage of workers in transportation.

a. High workforce percentage in manufacturing, 1961*

b. Diversified district industrial structure, 1961

c. Location on power grid, 1967

d. Location at a significant road and rail junction, 1967

2. Similarity in physical and economic characteristics

a. Topography and soil conditions

b. Corporate area per person, 1961

c. Population growth, 1951-61

d. Percent literate, 1961

e. Percentage of urban to district population, 1961

f. Percentage of workforce in transport, 1961

g. Percentage of workforce in construction, 1961

3. Availability of data

Evidence of varied industry and infrastructure as a basis for obtaining data on infrastructure requirements and costs.

4. Regional representation

Coverage of the principal subregions of the Indo-Gangetic plain in the three states

5. Representation of city size

Adequate coverage of cities in each size class represented in the study.

Cities in Clusters 1 and 2, which have high and average cluster mean values for employment in manufacturing, as described above, were mapped and cross-classified by size as the basis for sample selection. Through the use of supplementary information on citywide registered factory employment and per capita municipal expenditures, 15 cities from these two clusters were selected. The remaining three cities, Gorakhpur, Faizabad, and Amroha, were selected primarily to improve city size and regional

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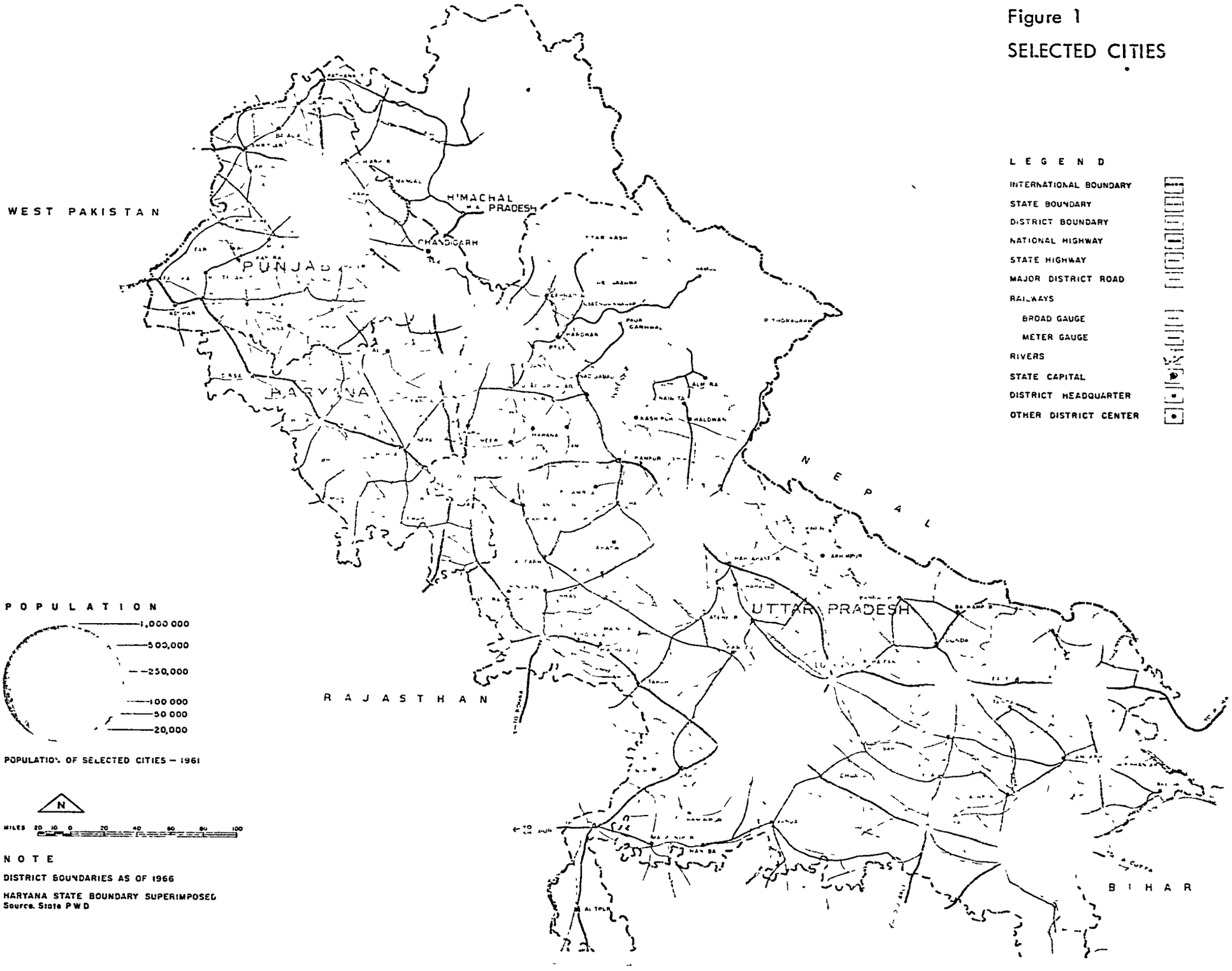
* Data on growth of manufactures were also sought but were unavailable for nonhousehold manufactures, by city or district.

representation in areas giving evidence of new economic potential, related to development of the fertilizer industry in Gorakhpur and the intensive agricultural program in Faizabad district.

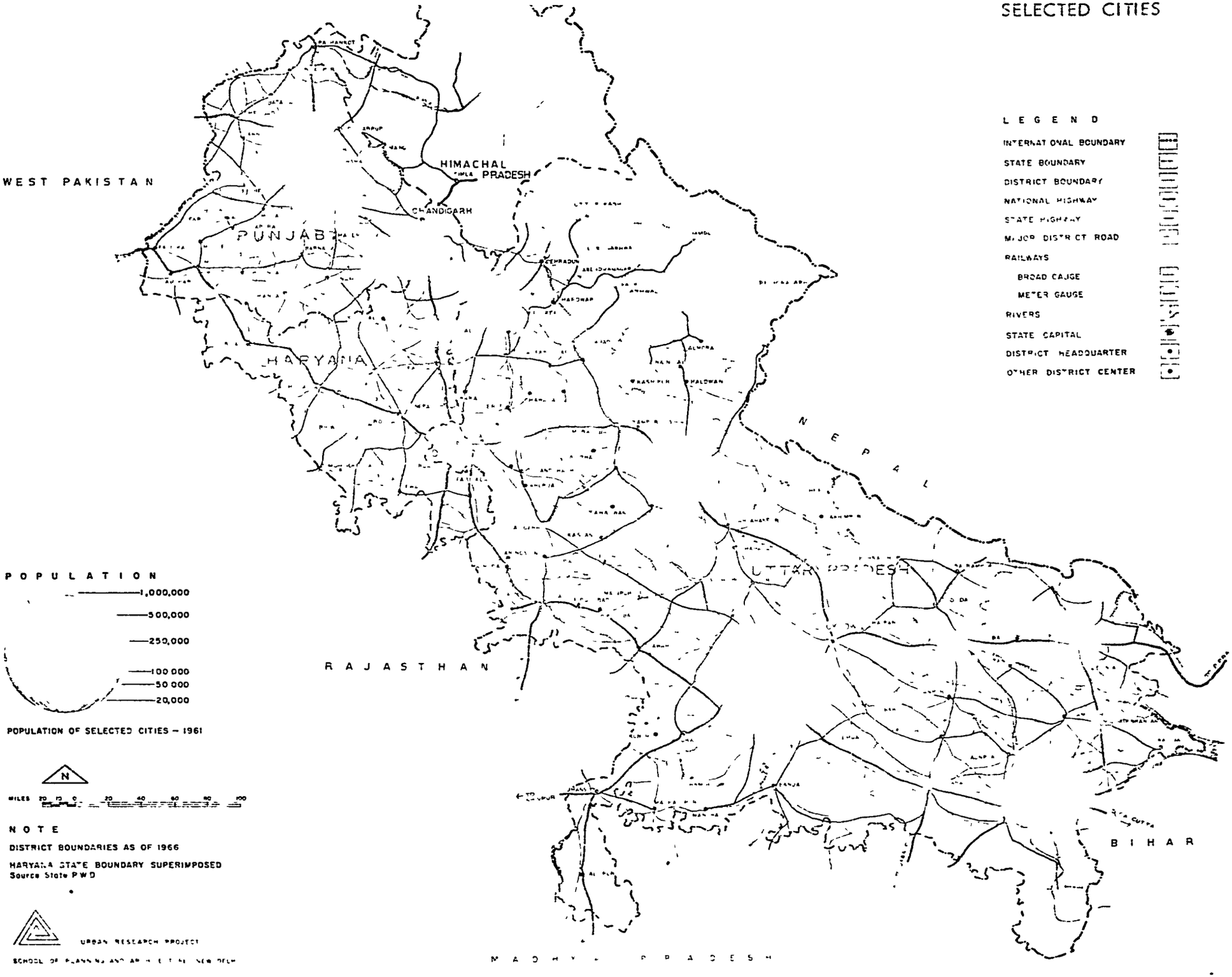
The selected 18 cities are indicated by size class on the study region map, Figure 1. Because the existing infrastructure features of these cities are relevant to an appreciation of incremental infrastructure needs, their detailed presentation is deferred until Chapter V. The reader who wishes to gain an overall understanding of facility characteristics in the 18 cities before proceeding to the next two chapters, on individual facility costs and industry requirements, may turn first to pages 243 to 259.

Figure 1

SELECTED CITIES



SELECTED CITIES



III COST ANALYSIS OF INDIVIDUAL FACILITIES AND SERVICES

The purpose of this chapter is to analyze the cost characteristics of the principal urban facilities and services required for industrial expansion. With respect to each facility, the analysis seeks to establish those e. gineering and other variables which re principal determinants of costs. Particular attention is given to economies and diseconomies of scale. This analysis is a prerequisite to the examination, in Chapter V, of the relationships through which size of city may influence requirements and costs of infrastructure elements, individually and collectively.

Cost Definitions and Assumptions

Consistent definitions relevant to widely varied types of facilities and services must be established in order to compare and combine the costs of such facilities. The cost definitions used generally in this study are stated below.

Total Annual Cost

Total annual cost is the sum of capital charges and current (recurring) costs and is the cost measure relevant for investment evaluation and also for testing the research hypothesis.

Capital Costs

Capital costs as defined in this report refer to the costs of physical facilities, including construction costs and the cost of equipment and its installation. Interest on working capital is not included in the analysis.

The weight of capital costs in total annual cost varies significantly among the principal types of urban infrastructure. Among other factors, this variation reflects the differing proportions in which physical facilities, represented in capital costs, are combined with personal or institutional services, reflected in current costs.* Variation is also caused by differences in economies of scale between physical facilities and personal services.

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* For a given facility, the ratio of capital to current costs may also vary with the quality of service rendered and the technology employed in production of the service. Factor costs and foreign exchange requirements, among other things, may influence the technology used.

The annual incidence of capital costs is, of course, dependent on assumptions made with respect to the discount or interest rate and the period of depreciation or amortization of the capital facility. The effect of economies of scale on total annual cost is correspondingly influenced by these assumptions, which are considered below

Calculation of Annual Capital Cost Equivalent. The main objective of the method of cost calculation adopted for this study is to be able to compare and combine costs incurred at different points of time, for facilities of different useful lives. For this purpose, we reduce the initial investment cost to the annual capital cost equivalent, or annual capital charge. Assuming constant annual operation and maintenance costs throughout the life of the facility, we add the annual capital charge to these operation and maintenance costs and thus get total annual cost.

The annual capital charge is the amount which, in a uniform series of end-of-year deposits over the life of an investment, has a present discounted value equal to the initial investment. It is most readily computed by use of a table of "capital recovery factors" for different discount rates and service lives.* In presenting annual capital charges for various facilities as computed for this report, the value of the applicable capital recovery factor will be shown. This procedure is based on the sinking-fund principle, which avoids distortions in comparisons over time introduced by other methods of accounting for depreciation.† It is, in effect, neutral as to the profile of depreciation, assigning the sum of investment costs, interest, and depreciation to each year uniformly.‡

For purposes of comparing returns or benefits or effectiveness to costs, the present discounted value of expected future costs is often more convenient than annual cost. Present discounted value is also more accurate if annual operating costs vary distinctly over time, more or less predictably. However, this study does not explicitly assess returns or benefits to individual facilities. If this is the purpose at hand, annual cost can readily be converted to present value. The capital recovery factor is the reciprocal of the present worth factor. Multiplying annual cost by the present worth factor gives present discounted value.

Interest or Discount Rate. Choice of the appropriate rate of interest for assessing returns to public or private investment has been widely discussed in recent literature on investment and economic growth.§

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* Eugene L. Grant, and W. Grant Ireson, Principles of Engineering Economy, 4th ed., The Ronald Press Company, New York, 1964, pp. 43-95.

† Richard A. Tybout, "Economic Criteria for Evaluating Power Technologies in Developing Countries," in Vol. I, Natural Resources, United States Papers prepared for the United Nations Conference on the Application of Science and Technology for the Benefit of Less Developed Areas, U.S. Government Printing Office, Washington, D.C., pp. 179-185, 191-201.

‡ Reference 76, p. 17.

§ References 127, 136, 145, 155.

The point at stake for the present study is the sensitivity of infrastructure costs to the interest or discount rate. The issue arises because use of a different discount rate shifts the relative weight of capital and current costs. Since proportions of capital and current cost vary greatly among different facilities, and are affected differently by economies of scale, the choice of interest rate may influence comparisons or summations of annual cost.

In calculating incremental costs in Chapter V, annual capital costs are computed at an interest rate of 10 percent, considered representative of the opportunity cost of capital in many developing countries.* To test the sensitivity of the cost conclusions to interest rate levels, comparisions are made with annual capital costs at 5 percent interest, closer to the bookkeeping rates used by many municipal agencies.

Optimal design of facilities or choice of technology to minimize the combined cost of capital, operation, and maintenance over time, or for alternative capital and labor costs, is also dependent on choice of the appropriate discount rate. However, such trade-offs between capital cost and annual maintenance are beyond the scope of this study. Data reported on first costs and maintenance costs are based on current practice, not on optimization, although the presentation of annual capital costs at two discount rates should facilitate further analysis of these trade-offs.

Depreciation. The annual capital cost of the flow of services from a facility is governed by the facility's economic life, reflected in the concept of depreciation, not by its particular annual debt charges, usually reflected in accounting concepts of amortization. Inasmuch as most of the public infrastructure facilities considered in this report are not characterized by rapid obsolescence, their useful economic life approaches their physical life. Relatively long periods of depreciation are therefore appropriate in measuring the annual capital cost of their services.† The depreciation period taken as appropriate for each facility or facility component is set forth in the respective cost section and in Appendix C.

Current Costs. Maintenance and Operation

Elements of maintenance and operation costs vary substantially among different types of infrastructure, as does their weight in total annual cost. The degree of detail presented for each facility is determined primarily by the quantitative significance of each cost element, but in some instances, also by limitations in availability of detailed cost breakdowns.

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* For a recent application of the 10 percent rate to investment analysis for India, see Alan S. Manne (Ed.), reference 136.

† Assuming, of course, appropriate maintenance over the life of the facility.

To the extent necessary and feasible, maintenance and operation costs are divided between fixed (e.g., permanent staff; periodic maintenance unrelated to use levels; administrative overhead) and variable costs (e.g., wages and salaries of temporary staff; materials, fuels, and supplies directly related to levels of output; replacement parts). Given the accounting methods generally in use for these public facilities, a complete classification of current costs into fixed and variable types is in many cases not possible.

Long Term vs Short Term Costs

The concern of this study is essentially with long term, not short-term costs. The focus of cost analyses in this chapter, accordingly, is on variation in costs as a function of the scale of each facility. The resulting cost tables and curves represent long term or "planning" costs, relevant for evaluating the size and costs of a facility against expected growth of demand over some time horizon. Conversely, the study is not basically addressed to short term cost changes that result from changes in the rate of utilization of existing capacity, whether below or above the output level at which minimum unit costs are realized.

On the other hand, short term variations are significant in the reporting, measurement, and analysis of historic costs. Procedures to eliminate or compensate for these short term effects are described in the relevant cost sections.

Costs of Land

Costs of land are so peculiar to each local situation that they have little general relevance for comparison of facility costs. Land costs are excluded from data reported in this chapter.

Both a location and a natural resource are obtained in acquiring land. As a location, land commands an opportunity cost, determined by the value of alternative or competing uses of the site.* As reported in Chapter V, land costs were taken into account in selecting candidate industrial and residential sites for cost estimation purposes in the five developmental cities. The influence of land costs on total infrastructure costs is noted in Chapter VI.

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* For discussion on the classical view of land as an indestructible resource for which public expenditure is to be regarded simply as a transfer payment, not a cost, see an exchange of Letters to the Editor, Journal of American Institute of Planners, Vol. XXXIII, No. 3, May 1967, by Philip H. Friedly and James C. T. Mao, pp. 181-183.

Cost Reporting and Development of Construction Cost Indexes for 18 Cities

Collection of valid cost information on projects of known specifications is a foundation of useful cost analysis. An understanding of prevailing contract administration and accounting procedures is in turn essential. The following brief description of contract practices at the city level in the field region sets the stage for interpretation of reported costs.

Construction Cost Administration

Execution of most public construction projects in the 18 cities, as indeed throughout India, is under supervision of executive engineers of state public works and related departments, or of municipal engineers and administrators. Projects are generally carried out through building or engineering contractors, although routine works as well as maintenance are usually performed departmentally. The executing agency prepares designs, specifications, invitations to tender (bid), and detailed cost estimates. On the basis of the detailed design specifications, the executing agency works out the bill of quantities, labor inputs, and corresponding cost estimate for each project. The basis of cost estimates is the approved schedule of rates for each state, which itemizes in detailed terms the standard bill of material quantities and labor requirements for various items of work. Small percentage variations from the state schedule of rates are authorized for regions and districts.

The contracting system is generally by "percentage rate contract."* The bidder is required to quote the percentage above or below the cost estimate at which he will be able to do the job. Experienced contractors work out their cost with knowledge of the approved rate for each item and also of current local variations in market rates for construction labor and materials. Difficulties may arise when quantities of some item change considerably during execution because of incorrect estimates, nonavailability or substitution of materials, change orders or modifications after the work is awarded, or construction delays. Increases of cost by more than 15 percent above the approved estimate require departmental authorization.

Interviews with public works engineers, municipal authorities, and informed contractors and architects at each point in this chain of construction responsibilities proved the best opportunity for research team members to discuss and evaluate recent project costs and their determining factors. Cost questionnaires providing for the necessary degree of detail

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* United Nations, Economic Commission for Asia and the Far East, Study on Building Costs in Asia and the Far East, 61/II·F/9, Bangkok, 1961, p. 20.

on construction specifications were given to respondents as orientation to the study.* The questionnaires, prepared for 12 major types of facility and service, were used in scrutinizing and recording cost information on projects carried out since 1956. The research team members, accompanied by local engineers, also observed on-site construction in process or recently completed, and these observations added to the judgments and information acquired in obtaining costs from departmental accounts.

Two prominent features of the existing system of contract administration and accounting caused difficulty in obtaining complete and relevant cost details: (1) the time taken to close out projects, and (2) cost breakdown practices.

Regarding (1), project accounts are frequently not closed out until two or three years after effective completion of construction. The closing of accounts must await signing of the project completion certificate by the cognizant authority, followed by review and final settlement of all outstanding financial claims in connection with the project. Usually the unpaid portion of incomplete accounts is only a minor part of total cost. Scrutiny of each record was needed to determine this fact. Many more final estimates of cost than actual costs were available for research, but it was decided at an early stage to give primary attention to the search and study of actual in-place costs.

Regarding (2), the breakdown of reported costs conforms, within accepted percentage variation, to the categories approved in the estimate, based on standard schedules. It is not possible to determine how far contractors' billing and subcontract practices permit different combinations or substitutions for the authorized amounts by category. For a full understanding of trends in cost elements or productivity, more specific detail would be necessary.† For the present research purpose of determining facility unit costs, however, it was possible to build an adequate grasp of component costs through successive study of the reported cost categories.

Development of Construction Cost Indexes

In order to analyze the costs of comparable facilities built at different times and places, and also to compare construction cost levels by size of city, a cost index is required for each principal type of construction, for each city. It was decided, through examination of the relative importance of labor and material requirements for various types of construction, that three principal indexes would be needed: for general construction, relevant for industrial housing, schools, hospitals, and

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* Appendix A includes a sample questionnaire on road construction costs.

† Accounts organized on the cost-based accrual system rather than the cash-based expenditure system would provide more specific cost information of the kind required for management control and productivity analysis.

other buildings; for bituminous roads of standard specification; and for overhead water storage tanks of reinforced cement concrete.

Two series of departmental cost indexes were available as starting points. On the basis of standard weights for cost components, the Central Public Works Department and Central Posts and Telegraphs Department, New Delhi, from time to time establish an index of construction cost for particular districts or towns, related to Delhi costs for a given year as base 100. For one or more years from 1962 to 1967, index numbers were available for 58 places in the three-state region, including 12 of the 18 cities selected for study. While no city was covered for enough years to establish trends, and component weights were not directly pertinent to the types of construction under study, through cooperation of the two departments it was possible to obtain original, unadjusted wage data on masons, carpenters, and unskilled labor as well as prices of six principal construction materials for 39 cities in the region, each city having data for one to three years in the 1962-67 period.

Wage and price data for 1965-67 were obtained in each of the 18 cities from contractors, material suppliers, construction trade workers, and engineers. In some instances, this procedure resulted in price data from two or three sources for a given city and year. Price data for 45 cities for each available year were arrayed by geographic region, and isolated points were removed. Both inspection and preliminary contour lines revealed systematic variation among the three states, and lesser variation among three subregions of Uttar Pradesh, in the construction wage rates and in prices for aggregate, sand, and timber. No locational pattern was evident in the substantial price variations for brick or the moderate variations for steel and cement. The latter two commodities had been under price control during most of the period.

In order to establish a complete price series for each city, it was necessary to interpolate prices for several years. The city's individual trend for the price in question was taken as the first guide to interpolation, assisted by the state or subregional mean trend. Final adjusted wages of three construction trades and prices of six construction materials for the 18 cities from 1962-67 are presented in Appendix A, Table A-1.

The resulting price series were put to two uses: preparation of cost indexes, and a multiple regression analysis of building costs by size of city. The latter analysis is described in Chapter V. As a basis for the general construction index, specifications for industrial housing projects of different types and sizes were drawn up by project engineers. Bills of material quantities and labor requirements were estimated with reference to the schedule of rates. The requirements for each building element were multiplied by the pertinent price for each city and year in a computer run, giving "total cost" for the specified construction by city and year. Taking total cost for Bareilly, 1965, as base = 100, the index value for each

point was computed by dividing its total cost by that of Bareilly, 1965.* As supplementary information, the printout provided the cost and index component for each building element, by place and year.

Parallel steps were taken to construct indexes for roads and water tanks, using similar price information on 11 additional trades and materials. The index for each type of construction is presented in the relevant section, while a comparison among all three indexes contributes in Chapter V to the discussion of costs as related to city size.

Comparative Analysis of Factors Influencing Costs

With northern India as the ground for direct exploration of costs, patterns of costs in other countries are also summarized in the following sections. This comparative analysis seeks first to identify the major variables which cause differences in unit costs. These may or may not be decision variables for all cases of facility design. Their identification calls attention, however, to the importance of cost determinants in facility planning. A second objective is to establish quantitative cost functions for use in two ways. To the extent that unit costs are a function of facility scale or of size of population or urban area served, the present analysis feeds into later examination of infrastructure needs as related to city size. Specifically, cost functions formulated here yield estimates of unit costs for application in the five developmental or test cities.

It is hoped that this systematic series of probes into the nature of costs in a wide range of facilities will stimulate research in other countries, toward increased understanding of factors conducive to effective cost management.

The sequence of discussion for each individual facility is in general as follows.

Functional components of the facility and its operation are first identified by relative cost importance, to assign emphasis in cost examination. If evidence is available of variation in the weight of the main components in different environments, this is presented.

Design variables are examined in the context of physical requirements and service standards for cities of different size. Ties between standards and costs are shown. Effects of economic and noneconomic factors on design variables are also noted. Legislative pressures or annual allocation

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* Bareilly was chosen for two reasons: it is centrally located in the region, and its computed "total cost" for general construction was virtually the same as the mean for all cities. The year 1965 was chosen as being close to the midyear of the index period.

practices, for example, frequently influence design choices or construction phasing, with corresponding effects on cost performance. To distinguish the consistent influence from the random influences is difficult, but account must be taken of them in analysis of reported costs.

The relative importance of labor, materials, equipment, and overhead in the cost of each facility is compared for the United States, India, and other countries, together with information on construction technology. Where relevant and feasible, economies of scale are analyzed on a comparative basis. This first involves a review and summary of previous quantitative studies. Where comparable projects have been studied, contrasts or similarities in the cost functions are pointed out. Scale effects are studied by regression analysis, when permitted by available data, both for costs reported in India and for costs from secondary sources not previously analyzed in the literature.

Annual maintenance and operation (AMO) costs are finally examined, leading to summary tables, which set forth annual capital and AMO costs for the facility size ranges relevant for industrial development in the cities under study.

Analysis of Individual Facilities and Services

Roads

Effective city road systems are of major importance to the location of new industries in developing countries, especially with increasing truck movement of raw materials and manufactured products. In this section the word "road" is used as a single descriptor for paved roads--city streets, state and district highways, and national highways. National highways, however, were considered only where constructed in the immediate geographic area of the cities studied. Differences in construction characteristics of national highways and city streets require separate analysis of costs.

Road costs, being remarkably representative of the type of traffic system and engineering practice for a region, have many variables which limit an accurate economic study. However, an attempt is made here to evaluate the underlying forces of operation within the limitations of data and context applicable to India.

Influence of Principal Variables on Unit Costs. The principal components of cost include right-of-way (land); earthwork and ground surface preparation (excavation, removal of poor soil, addition of good soil, embankment, grading); base course (gravel, stone, brick, and their compaction); drainage, culverts, and bridges; pavement or surfacing* (metalled

* In India, this chiefly pertains to "road section" cost. Road section includes base, paved surface, and side berms (if any).

surface--bituminous, concrete, or macadam) and maintenance (the upkeep of the road after construction). Right-of-way costs are not considered here. Classifications of the main components are not always the same, precluding full comparison, but the range of variation is suggested in Tables 5 to 7.

Terrain, soil type, and climate have primary influence on earthwork and related components, as indicated in Table 5 by the comparison for Venezuela between mountain and llanos regions (extensive plains). Geography also influences the cost of base courses, shown in Table 6 by the range from minimum to maximum percentage breakdowns of cost elements for U.S. highways. These are first costs converted to an annual basis using 7 percent interest. In the "maximum" situation, base or surfacing material is imported from a considerable distance, produced by crushing quarried rock, or both. In the "minimum" case, the base material is available close by in a gravel bank, stream bed, or similar source. The base and pavement, combined in the "road section" category in India data (Table 7) usually form the largest part of costs, with some exceptions, as shown in Tables 6 and 7.

Table 5

EFFECT OF TERRAIN ON COST OF ROAD ELEMENTS IN VENEZUELA

Road Elements	Percent of Total Cost: Llanos Terrain	Percent of Total Cost: Mountainous Terrain
Preparation of site	7.0%	6.0%
Earthwork	37.2	48.6
Culverts and drainage	16.0	12.9
Base	7.7	10.2
Bridges	30.1	20.8
Fencing	2.0	1.5
Total	100.0%	100.0%

Source: Richard M. Soberman, Transport Technology for Developing Regions: A Study of Road Transportation in Venezuela, The M.I.T. Press, Cambridge, Mass., 1966, p. 45.

Table 6

SUMMARY OF DERIVED ANNUAL COSTS OF U.S. CONSTRUCTION FOR VARIOUS ROAD WIDTHS
(Straight, Level Road)

TYPE OF ROAD: SURFACED--2" ROAD MIX ASPHALT

Roadbed Width (ft)		Embankment	Base (6" gravel)	2" Road Mix	Drainage	Seal Coat at 8 yr	15% Eng. & Superv.	Total
		(dollars per mile)						
16	Min.	$ 497	$ 121	$ 433	$ 253	$ 47	$ 208	$ 1,554
	Max.	497	538	433	253	47	265	2,033
18	Min.	519	131	473	264	51	216	1,654
	Max.	519	582	473	264	51	288	2,172
20	Min.	541	141	514	274	55	229	1,754
	Max.	541	626	514	274	55	303	2,312
22	Min.	562	151	555	285	58	242	1,853
	Max.	562	671	555	285	58	320	2,451
24	Min.	583	161	595	295	62	254	1,950
	Max.	583	715	595	295	62	358	2,588
30	Min.	644	191	717	327	73	293	2,245
	Max.	644	847	717	327	73	391	2,999
36	Min.	701	220	839	359	85	331	2,535
	Max.	701	980	839	359	85	445	3,409
		(percent)						
18	Min.	31.4%	7.9%	28.6%	16.0%	3.1%	13.1%	100%
	Max.	23.9	26.8	21.8	12.2	2.4	13.0	100

Note: Detail may not add to totals due to rounding.

Source: Based on C. H. Oglesby and M. J. Altenhofen, The Economics of Design Standards for Low-Volume Rural Roads, Stanford University, Dept. of Civil Engineering, July 1967, p.89

Table 7

RELATIVE IMPORTANCE OF ROAD COST ELEMENTS IN INDIA
(Bituminous Highways)

City	Year	Length of Road (miles)	Cost Elements (percentage)					
			Embankment	Road Section*	Culverts & Bridges	Signposts & Street Furniture	Arboriculture	Overhead & Others
Patiala	1967	6.10	11.7%	75.4%	10.5%	0.5%	--%	1.8%
Patiala	1967	8.10	9.2	76.3	14.3	0.2	--	--
Karnal	1966	6.57	27.7	46.2	16.2	0.5	0.9	8.5
Ludhiana	1966	6.85	25.3	61.5	--	0.5	7.5	5.3
	Weighted average		17.75	62.35	9.85	0.40	2.0	7.65

* Road section includes base, paved width, and side berms wherever applicable.

Source: Construction projects reported in field study.

Standards, transportation objectives, technology, and skills influence pavement costs. Pavement thickness and hence pavement costs depend basically on the characteristics of the subgrade soil, and the volume and composition (axle load) of the future traffic anticipated. However, the significance of these factors often differs between developed and developing regions, especially in the context of efficiency and economic constraints. In his study, Soberman* summarizes: ". . . Where highway agencies have limited funds, as in the case of developing regions, pressures are for new construction as opposed to maintenance of existing plant. The political worth of a newly constructed highway generally outweighs the value of a well maintained one . . Moreover, because funds are usually allocated to highway agencies on a year-to-year basis by legislative bodies, there is often considerable uncertainty that funds will be available for periodic maintenance. Without adequate maintenance (particularly in tropical climates) new roads deteriorate rapidly unless constructed to high standards. Poor law enforcement and uncertainty as to adequate maintenance practices thus tend to favor the overdesign of roads in undeveloped regions."

However, in many regions, it is doubtful that overdesign is a consistent outcome of financial and political pressures. Other factors--such as preponderance of mixed traffic, wagons with narrow steel rimmed wheels, and accessibility of road-making materials (especially stone aggregate)--influence the design criteria. Soil conditions, traffic volumes where axle loads are uncertain, and the necessity for stage construction greatly influence the choice of type of pavements, i.e., rigid or flexible. Current research on both engineering and economic aspects of road design could lead to changed cost profiles of road pavements, construction, and maintenance.†

Proportions of labor, materials, and equipment as components of road costs vary substantially in different economies. This is seen in Table 8, despite lack of full comparability in the cost categories shown.

Economies of scale in road projects pertain both to the width of road, which is an inherent function of design requirements, and to the length of road constructed at one time, which is often a function of contract practices and/or budget restraints. Effects of width are seen in the engineering assumptions that underlie Table 6. For example, a doubling of road width from 18 feet to 36 feet increases annual capital cost per mile by 53-57 percent, but on a total area basis, there is a reduction of 22-24 percent in cost per 100 square feet. Oglesby and Altenhofen explain that unit costs for quantities in excess of those required for a 16-ft minimum width were reduced by 25 percent in estimates for all road elements except drainage, "to recognize the fact that increments added to a basic design have lower costs than average."‡

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* Reference 65, pp. 6-7.

† Mashar-ul-Haq Saeed Ahmad and M. R. Chughtai, Study of Relative Economics of Various Types of Road Surfaces, Road Research Institute, Lahore, Pakistan, no date, 40 pp.

‡ Reference 64, pp. 6 and 274.

Table 8

VARIATION IN L'BOR AND MATERIAL COSTS
FOR ROAD CONSTRUCTION
(Percent)

Item	Costa Rica (1961) Earthwork	Earth Sub-base	Gravel Case	Bitumen Surface	Drainage	Item	India* 1967	U.S. 1964
Labor	18.8%	20.1%	16.5%	10.6%	12.1%	Labor	12%	26.0%
Local materials	0	4.9	21.2	8.4	60.3	Materials	84	50.3
Local capital	16.5	14.2	13.2	12.9	9.4	Equipment	4	11.1
Foreign exchange-materials	17.2	26.5	19.3	42.1	8.9	Other	0	12.6
Foreign exchange-capital	47.5	34.3	29.8	26.0	9.3			
Total	100.0%	100.0%	100.0%	100.0%	100.0%		100%	100.0%

* Road section costs for bituminous roads, stone ballast.

Sources: Costa Rica: Cited in Armando M. Lago, Intercity Highway Transportation Cost Functions in Underdeveloped Countries, Ph. D. dissertation, Harvard University, 1966, p. 111.
India: Field studies.
United States: U.S. Bureau of Labor Statistics, Labor and Material Requirements for Construction of Federally Aided Highways, Report No. 299, 1966.

Little analysis has been made of economies of road construction cost by physical length of project. A study of 40 projects in the state of North Dakota in the United States related total project cost to excavation yardage, finding lowest average cost per cubic yard in projects approximately 7 miles long.* A quadratic equation produced the best fit, unit cost falling sharply for projects from 1 to 3 miles in equivalent length. Estimated unit costs for projects of yardage equivalent to 3 miles were 13 percent above projects 7 miles in length. At around 9 miles equivalent, unit costs tended to increase slightly. It appears that there is some agreement among professional peers that projects of about 6 mile length offer some economy of scale.† Isard and Coughlin, citing the Doyle study and interviews with Massachusetts highway engineers, indicate construction scale economies over the range from 1 to 20 miles but of negligible degree beyond 10 mile lengths.‡ Clearly, the existing studies are inconclusive.

Road Maintenance Costs. From the time asphalt or concrete highways are constructed until they are resurfaced, maintenance operations are carried out in order to maintain them in a condition that is consistent with each agency's standards of smoothness and safety.§ In the present study, maintenance cost means the physical maintenance** costs of "road surface" segments only.

An SRI study of maintenance costs (in 12 states of the United States) shows that over road life for both asphalt and concrete types of pavement, they tend to average $250 per mile per year (Figure 2). Asphalt maintenance costs begin at an estimated $50 per mile per year, rise to an average peak of $300 at the time asphalt is resurfaced (18 years), and then decline. Concrete costs start at about $75 per year, rise rapidly for the

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* John M. Doyle, "How to Determine Economic Project Size," Roads and Streets, Vol. 83, October 1940, pp. 66-68.

† See Great Britain, National Economic Development Office, Efficiency in Road Construction, a report by a working party of the Economic Development Committee for Civil Engineering, HMSO, London, 1966. "At present, it is generally accepted by all sides of the industry that a new length of motorway should normally be divided into contracts of about six miles, provided that the length of new road affords satisfactory connections with other roads, but this rule does not appear to have been arrived at by any analytical process."

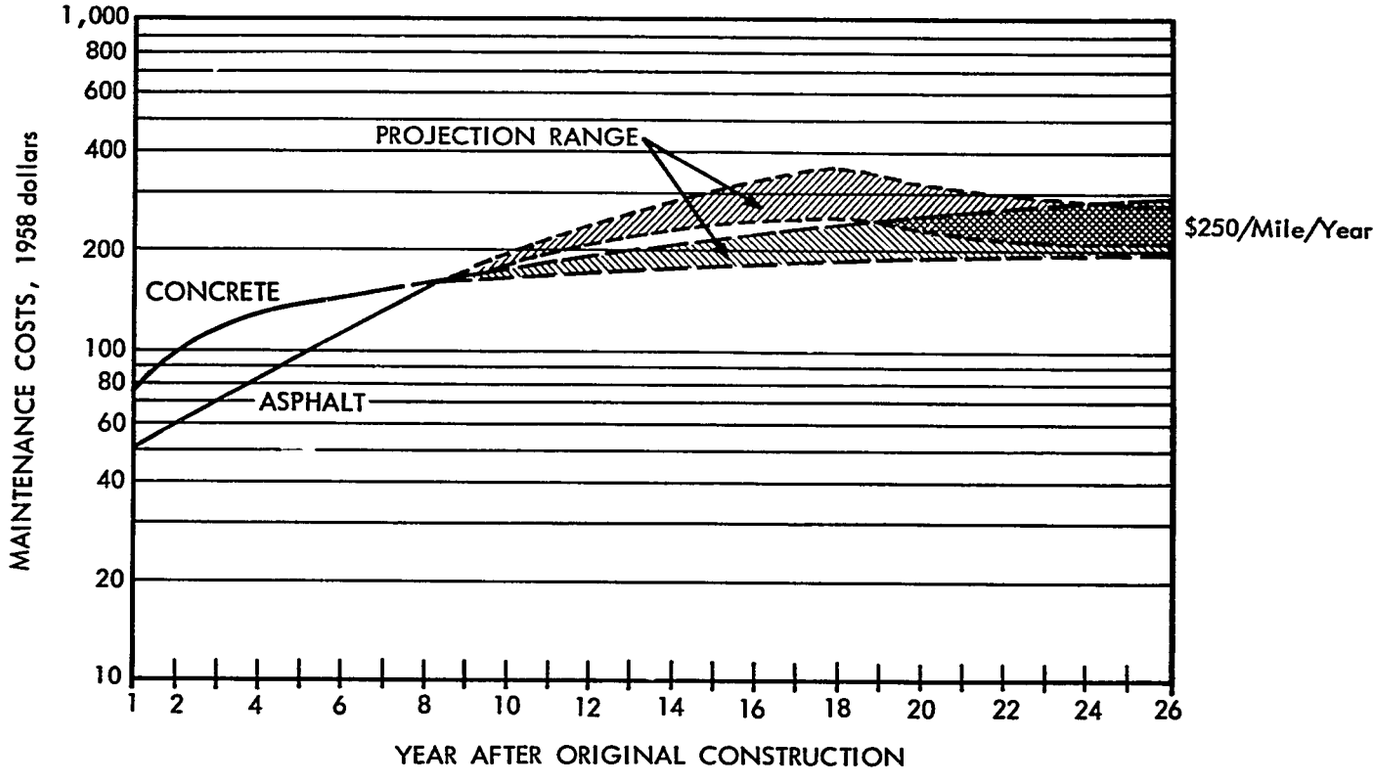
‡ Reference 39, pp. 64-65, 68.

§ Stanford Research Institute, Economics of Asphalt and Concrete for Highway Construction, April 1961, p. 83.

** Physical maintenance: "The preservation and upkeep of a highway, including all of its elements, in as nearly as practicable its original or constructed condition or its subsequently improved condition . . ." American Association of State Highway Officials, Manual of Uniform Accounting Procedures, Washington, D.C., 1968.

Figure 2

ASPHALT AND CONCRETE MAINTENANCE COSTS, CUMULATIVE AVERAGE OF DIRECT TRAVELED-WAY MAINTENANCE



*Includes labor, material, and equipment costs only.

SOURCE: Stanford Research Institute, Economics of Asphalt and Concrete for Highway Construction, April 1961, p. 17.

first several years, and then gradually increase until the pavement is resurfaced (26 years).* The Institute attempted to establish correlations between annual maintenance costs of each pavement and traffic volume, depth of travelled way, and other variables. Other than a tendency for maintenance costs to decrease as traveled-way depth (and strength) increase, no significant results were obtained.† The approximate breakdown of costs for traveled-way and base maintenance, without regard to pavement type, was: ‡

	Percent of Total Maintenance
Labor	50%
Materials	30
Equipment (includes direct operating expense and depreciation)	20
Total	100%

In comparing initial and maintenance costs, a report[83] published by the U.S. Highway Research Board states, "For the majority of pavement sections covered by this study, the initial construction costs constituted 85-95 percent of the total annual costs while maintenance costs amounted to less than 10 percent of the total annual costs." A distinctly different proportion is experienced in cities studied in India, as will be seen below.

Analysis of India Field Data. Field data collected were for national and state highways and city streets, mainly of asphalt and concrete. The majority of the roads were single lane with a paved surface 12 feet wide. There were some exceptions of 10 and 15 feet widths in city streets.

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* SRI, op. cit., p. 84. The report mentions that "the reasons for rapid increases in costs over the first several years are not apparent . . . . Barring major failure (which might require resurfacing), concrete maintenance over time consists mainly of joint and crack repair and, possibly, mud jacking or underscaling prior to resurfacing. Joint and crack repair should logically show a slight upward trend as the pavement gradually deteriorates under repetitive traffic loads."

† SRI, op. cit., p. 85.

‡ SRI, op. cit., p. 158.

One of the main problems in analyzing the data stems from the many different methods and situations for road construction. The majority of the national and state highways have earth compacted side berms with or without side drains. Nearly 50 percent of the city streets have no side berms or side drains. The right-of-way varies from the minimum 10-12 feet in city streets to the maximum 80 feet in highways.*

The majority of the pavement or surfacing is bitumen (asphalt). Surprisingly, in three small cities, concrete roads were encountered as city streets. In eastern Uttar Pradesh, some state highways had water bound macadam (WBM) surfaces using locally available Kankar stone.†

There were two distinct categories in the bituminous roads, the difference being mainly in the base course where either stone ballast (aggregate) or brick ballast was used. The brief specifications for these roads were:

	Specification Type A	Specification Type B
Base Course	4-1/2" stone ballast consolidated to 3"	4-1/2" brick ballast consolidated to 3"
Soling Course	3" flat brick	3" flat brick
Wearing Course and Top Course	Two coats of bitumen painting with 60-70 lb of asphalt and 6.5 cu ft of grit for 100 sq ft of road surface	Two coats of bitumen painting with 60-70 lb of asphalt and 6.5 cu ft of grit for 100 sq ft of road surface

Most of the national and state highways and city streets were of specification A.‡ In some parts, especially eastern Uttar Pradesh, specification B was in use. This was mainly in the form of substitution of stone ballast by brick ballast because of nonavailability of stone locally or the heavier cost of transport of stone from distant quarries.

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* There are certain exceptions where the right-of-way is as high as 130-150 feet.

† Kankar - locally available low quality stone.

‡ There were other specifications in the wearing course like 3/4" premix carpet.

Generally, the execution of national and state highway projects in the region is carried out by the state PWD through contractors. The preliminary work like acquisition of land, preparation of road designs and estimates, invitation to tenders, etc., is done by PWD. This cost is borne on the total project cost and generally varies from 3 to 5 percent.* The contracting system is generally by "percentage rate contract."† In road construction, the contractor chiefly provides the labor element. Road rollers and materials like asphalt and stone aggregate‡ are provided by the PWD through its own channels. The completion of a single project is mainly dependent on the length of the road. No accurate data are available on physical length of project and time of completion. It was observed during field studies that longer projects were in some instances divided into sections of a mile each and contracts were awarded to different contractors. Generally, it was observed that projects 4 miles or more in length took more than a year to complete.

Execution of city streets is by the local authorities and generally follows the same pattern in award of contract. Asphalt, and sometimes road rollers, are provided by the local authorities.

In the analysis of road construction costs, sufficient data were not available to consider separately the variation of each cost element for changes in traffic volume or design standards. Highways constructed in the region by the PWD are mostly of the same design standards, since they conform to the standards prescribed by such national organizations as Indian Road Congress and Indian Standards Institution. The majority of the city streets follow the same standards.

The economic analysis of road section costs implicitly assumes uniform design standards and traffic conditions.§ As a basis for cost comparisons, the major components of road materials and labor for a one-mile stretch of uniform metalled width were identified. Calculations were made of the quality of each road course, such as base, soling course, and wearing course, and these were further broken up into items of basic materials, labor and equipment. The road cost indexes, Table 9, were the result of multiplying the requirement of each item in the standard Type A bituminous road by labor and material prices for the 18 cities.

Percentages of cost going into basic items for the three main types of road section are shown in Table 10. The labor percentage is higher

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* For highways, it is usually 5 percent.

† See details of the system, page 59.

‡ In Uttar Pradesh, sometimes the stone aggregate is provided on site by a different contractor, or the quarries for supply are specified.

§ Axle load, thickness of crust, and road capacity would be the same for the same design factors and traffic standards.

Table 9

CONSTRUCTION COST INDEX FOR BITUMEN ROADS
18 Cities, 1962-67
(Bareilly 1965 = 100)

State and City	1962	1963	1964	1965	1966	1967
Punjab						
Jullundur	82	84	86	88	91	98
Phagwara	80	86	95	101	108	115
Ludhiana	83	87	91	94	99	106
Patiala	75	80	86	87	91	94
Haryana						
Ambala	79	86	93	97	101	108
Jagadhri-Yamunanagar	72	78	84	88	90	94
Karnal	77	83	91	94	96	103
Bhiwani	70	75	81	84	87	91
Uttar Pradesh						
Saharanpur	63	68	73	76	79	86
Modinagar	73	79	86	89	94	105
Hapur	72	78	84	88	92	103
Amroha	70	75	80	83	88	97
Bareilly	82	88	96	100	106	119
Kanpur	98	107	109	112	120	134
Faizabad	95	103	113	118	125	132
Gorakhpur	95	104	113	117	122	136
Maunath Bhanjan	102	112	122	127	129	155
Varanasi	96	104	114	118	127	146

Table 10

PERCENTAGE COSTS OF ROAD MATERIAL AND LABOR
Road Length = 1 mile
(Bareilly 1965 = 100)

Bituminous Road*		
Material‡ and Labor	Type A	Type B
Bricks	22%	22%
Stone aggregate	37	34§
Grit	7	7
Asphalt	18	19
Unskilled labor	12	15
Roller	4	3
	100%	100%

Cement Concrete Road†	
Material‡ and Labor	Percent
Cement	50%
Course sand	1
Stone aggregate	20
Brick ballast	19
Unskilled labor	10
	100%

* Width 12 feet.
† Width 10 feet, 4" cement concrete (1:2:4) over 4" brick ballast base course. No equipment is used for compaction.
‡ Material costs at site of work.
§ Brick ballast.

Source: Field study.

for bituminous than for cement concrete roads, mainly because of the greater work required in spreading aggregate and grit. This difference is increased, as shown in the table, for Type B bitumen roads with brick ballast.

Three types of data were obtained for each road construction project reported in the field cities: total road section cost per mile, average surfaced width (since width sometimes varied in a single project, especially city streets), and specifications. Comparisons considered only road section costs to exclude local variations in earthwork, drainage, etc. Average costs for projects of comparable specifications are shown in Table 11 for the three main types of road. It will be noted that Type B bitumen roads cost 4 percent less than Type A, and cement concrete roads 23 percent more.

Unit road section costs in rupees per 100 square feet of paved surface are listed in Table 12 by length of construction project. In national and state highways, unit costs for bituminous roads range from the low Rs. 47 to the high Rs. 103, and in city streets the range is from the low Rs. 53 to the high Rs. 86. Particularly in the higher end of the range, unit costs tend to increase with length of project.

To explore the relationship between costs and length of project, least square curve fits were estimated for the data in Table 12.* Estimates based on the smaller number and range of cost points for city streets were not statistically significant. A linear equation for highway unit costs was statistically significant at the 1 percent level.† The plot of highway cost points, however, suggested a quadratic form, which produced a somewhat better fit.‡ The resulting quadratic equation is:

$$C_u = 65.62 - 6.09X + 1.21X^2$$

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* The regression results reported in this chapter were computed on a regression program that automatically tests the fit of several curve types to each set of input data. Since a relatively limited number of field cost observations were available for statistical analysis, it cannot be inferred that the resulting functional form is necessarily the "correct" relationship between quantity and unit cost, even though statistically significant. The validity of results on the shape of each cost curve is separately considered in the text for each facility. In particular, it is not safe to make assumptions about the shape of the curves as quantities increase or decrease outside the range of the data inputs.

† The linear equation results in $r^2 = .514$, $r = .716$. For $(N-2) = 10$, $r_{.995} = .708$; hence the hypothesis that the correlation is 0 is rejected at the 1 percent level of significance.

‡ The quadratic equation results in $r^2 = .621$ and has somewhat smaller percentage deviations between estimated and actual costs than the linear form, especially for projects of shorter length. The standard error of estimate is, however, substantial. In rupees, the mean value of C_u = 74.75, the standard error of C_u = 18.11, and the standard error of estimate of C_u = 12.33.

where C_u = cost per 100 sq ft of road section in rupees

and X = length of road section in miles.

Setting the first derivative equal to zero, C_u is minimum when $X = 2.52$; the corresponding C_u is 57 95. It appears that the unit cost is minimum at Rs. 58, for road projects of 2.5 miles length. The curve for this equation falls for increases in the value of X up to 2.5 and rises beyond $X = 2.5$.

It may be tentatively concluded that road projects tend to have least unit costs at around 2.5 miles length under present construction conditions in the study region. However, in view of the limited number of comparable costs which it was possible to analyze and the substantial standard error of estimate in the resulting equation, we base the cost estimates of Chapter V on the mean value of Rs 75 per 100 square feet for the roads examined, instead of on the estimating equation

Indian Road Maintenance Costs. In road cost analysis, maintenance costs are by far the most difficult data to acquire because of the variety of factors that influence the pattern of maintenance costs for various road types The pavement width, the impact of number of axle-loads on pavement, the daily traffic volume, the geometric design characteristics of the road, and the topographic and precipitation characteristics of the region are some of the major factors of maintenance expenditure

The major significance of maintenance costs is in their interrelation to capital expenditures and vehicle operation costs and effect on transportation policy as a whole.[59] Sufficient data are not available on vehicle operating costs, traffic volumes, and life of different pavement surfaces to analyze these factors in the field region.

Table 11

AVERAGE CONSTRUCTION COST BY TYPE OF ROAD
(Bareilly 1965 = 100)
Selected Indian Cities
1956-1967

Road Type and Surface Width*	Cost (Rs. per mile)	Percentage Relation to Type A
Bitumen Type A, 12 feet	51,650	100%
Bitumen Type B, 12 feet	49,625	96
Cement Concrete, 10 feet	63,500	123

* For specifications, see Table 6 and Table 10.

Source: Field study.

Table 12

UNIT COST OF BITUMINOUS ROADS BY LENGTH OF PROJECT*
(Adjusted to Bareilly 1965 = 100)

	City	Year Completed	Length of Road (miles)	Unit Cost (Rs. per 100 sq ft)
Highways	Patiala	1967	8.10	103.22
	Karnal	1959	8.07	85.97
	Ludhiana	1961	8.01	89.68
	Ludhiana	1964	6.85	84.41
	Karnal	1956	6.57	70.69
	Patiala	1967	6.40	95.80
	Phagwara	1966	5.40	61.69
	Ambala	1966	1.55	52.90
	Ambala	1965	1.40	52.63
	Patiala	1964	0.57	77.81
	Jullundur	1960	0.40	74.83
	Ambala	1967	0.36	47.38
			(feet)	
City Streets	Varanasi	1966	5,000	62.86
	Patiala	1963	2,995	84.06
	Karnal	1963	1,350	73.05
	Karnal	1967	1,300	65.00
	Kanpur	1966	1,219	65.94
	Patiala	1966	1,160	52.56
	Patiala	1965	774	66.83
	Jullundur	1967	650	86.08
	Phagwara	1966	382	80.11

* Bituminous Type A, 12 ft metalled width.

No sufficient maintenance costs were available for city streets. It appears that this is mainly due to handicaps facing local bodies in the upkeep of roads--the lack of funds and technical staff at such small administrative units. An analysis of data gathered on highway maintenance expenditures shows great variations (Table 13). Local environmental conditions, fluctuating annual budget allocations, and lack of appropriate accounts are factors explaining these variations. Nevertheless, the analysis shown in Table 13 gave a weighted average maintenance cost per mile of Rs. 2,868, a value that is very close to the standard of Rs. 3,000 per mile used in estimates by public works departments.

Table 13, the service life of asphalt pavement is assumed as 18 years* and the capital recovery factor is applied for two interest rates, 5 and 10 percent. The maintenance cost ranges from 16 to 60 percent of annual capital cost at the 10 percent value of the latter. When added to the weighted mean of Rs. 7,352 for annual capital cost at 10 percent, the mean maintenance cost at Rs. 2,868 equals 28 percent of total annual cost. This is significantly higher than the share of maintenance reported for the U.S. comparisons earlier.

Converted to Rs. 4.53 per 100 square feet, the mean maintenance cost shown in Table 13 is used in the estimates of Chapter V.

Cement Concrete Roads. There are not many cement concrete roads in the study region. However, in three smaller cities, some of the city streets are of cement concrete surface. Although available data are not sufficient (Table 14) for analysis, one significant conclusion derived from the table is that there is not much variation in unit costs by length of the project (average unit cost = Rs. 126.75 per 100 sq ft). This is expected since 50 percent of the total cost (Table 10) is cement, the price of which is governed by many other external factors of the economy.

During the field study, it was observed that the cities chose rigid payment, despite its high initial cost, for reasons other than economic.† No maintenance data for the rigid pavements were available. The need for practically no maintenance in the initial years was also quoted as one of the reasons for the choice of rigid payment for city streets.

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* Service life for pavements assumed based on studies in developing and developed regions. See reference 65, p. 71, ". . . Pavement lives of 17 years have been assumed that correspond to average experience for well constructed flexible payments." See also reference 63, p. 154.

† Some of these roads were experimental, since the construction was associated with a cement manufacturing company that promoted its products by providing technical help.

Table 13

HIGHWAY EXPENDITURES:* INITIAL COST, ANNUAL CAPITAL COST, MAINTENANCE COSTS
1967
(Bituminous road length - 1 mile, metalled width - 12 ft)

City	Length of Project (miles)	Year Constructed	Initial Cost† (Rs.)	Annual Capital Cost‡ 5% (Rs.)	Annual Capital Cost‡ 10% (Rs.)	Maintenance Cost§ (Rs.)
Ludhiana	8.01	1961	60,158	5,147	7,335	1,206
Karnal	6.57	1956	46,677	3,993	5,691	3,659
Karnal	8.07	1959	56,201	4,808	6,853	1,085
Jullundur	11.50	1959	35,046	2,998	4,273	2,632
Jullundur	13.62	1959	90,698	7,753	11,059	4,720
Weighted average				5,157	7,352	2,868

* Road section costs.
† Adjusted to 1967 (Bareilly 1965 = 100).
‡ Interest at 5% and 10%; service life of asphalt pavement 18 years. Capital recovery factors (CRF)=0.08555 and 0.12193 respectively.
§ Average of 1966 and 1967 costs adjusted by index.

Source: Field study.

Table 14

CEMENT CONCRETE ROADS
(Unit Cost by Project Length)

City	Year	Length (ft)	Unit Cost* (Rs./100 sq ft)	Index†	Adjusted‡ Unit Cost (Rs./100 sq ft)
Amroha	1965	450	119.5	88	135.7
Amroha	1965	500	116.5	88	132.4
Karnal	1966	630	127.0	103	123.3
Amroha	1966	660	123.5	94	131.4
Bareilly	1962	1,528	83.0	74	112.1
Maunath Bhanjan	1964	3,300	147.0	117	125.6
Average unit cost					126.8

* Road widths vary from 10-15 ft and the unit costs are per 100 sq ft of paved area.
† Index for cement concrete roads worked out for these cities only.
‡ Adjusted to Bareilly 1965 costs.

Source: Field study.

Water

The existence and growth of urban communities depend in part on clean, potable, and plentiful water supplies. Every urban activity is directly or indirectly a water user.* The quality of water for many household, industrial, and civic uses must meet prescribed standards. Urban water supply, therefore, holds a strong and important position in the infrastructure facilities for urban areas. By the same token, urban water costs stand somewhere near the top in the hierarchy of infrastructure cost analysis.

Principal Determinants of Costs. How water service is provided and priced has important effects upon the internal growth patterns of the urban area, and to some extent may condition urban land use patterns. Cost records on urban water systems, generally, apply to specific localities. Few good analyses are available on the determinants of the construction, operation, and maintenance costs of water systems under different conditions. Even the data available must be interpreted with qualifications because of the many variables involved. Water demand, for example, is progressive. Water treatment costs vary widely depending on the nature of the raw water and the quality of supply desired.

The investment for supply may vary from nearly zero as in the case of adjacent available surface water to substantial as in the case of deep well drilling or extensive conduit systems. The costs for pumping stations are a function of maximum demand load, lift, and transmission distances. The major investment is generally the distribution system, which includes main piping or conduits from the source and distribution lines to the consumers. Given these diverse factors, the relative importance of individual elements in total investment varies greatly. The following estimate based on overall experience in the United States is presented as an illustration.†

	Percent
Supply	8.3%
Pumping stations	17.1
Reservoirs	5.6
Distribution system	53.0
Filter plant	11.8
Real Estate	4.2
Total	100.0%

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* J. W. Milliman, "Policy Horizons for Future Urban Water Supply," Land Economics, Vol. XXXIX, No. 2, May 1963, p. 109.

† Reference 74, p. 9. See also Ernest W. Steel, Water Supply and Sewerage, 3rd ed., McGraw-Hill, New York, 1953, pp. 548-549. Also see Louis Koenig, "The Cost of Water Treatment by Coagulation, Sedimentation, and Rapid Sand Filtration," Journal of the American Water Works Association, March 1967, pp. 290-335.

The unit costs of a water supply system are related to its hydraulic capacity, which, as an element of design, is determined by: (a) future population estimates for a specified year, (b) the per capita water consumption value selected and (c) delivery pressure or pressure range at point of use. The degree of utilization, which is related to existing local socioeconomic and water supply conditions, also significantly affects unit costs. This is best summarized in the study by Dieterich and Henderson:*

> In view of the major deficiencies in urban water system construction that need to be met, it seems highly appropriate to conserve capital and material resources as much as possible in the design and construction of individual water systems. By restraining construction costs, water rate increases can also be held in check, not only with respect to the costs of construction but also in view of the fact that operating and maintenance costs are lower as a result of smaller system capacities . . . per capita water consumption design values employed in developing countries cannot be directly compared without adequate information on socio-economic conditions (including housing and cultural practices) and climatic factors. This is illustrated by the following example of two cities in two different developing nations:

(1) Design factors	City A	City B
Connected population	5%	75%
Served by public hydrants . . .	95%	25%
Per capita water use	150 l/c/d†	150 l/c/d
Total population	100,000	100,000
Average daily water supply . . .	15,000 m^3‡	15,000 m^3
(2) Analysis of beneficial domestic water use		
Public hydrants at 20 l/c/d . .	1,900 m^3	500 m^3
Minimum connected 60% at 40 l/c/d	---	2,400 m^3
Connected-intermediate 10% at 80 l/c/d	---	800 m^3
Connected-fully equipped 5% at 120 l/c/d	600 m^3	600 m^3
Sub-total	2,500 m^3	4,300 m^3
Percentage available for commercial and industrial uses and all non-beneficial consumption (leaks and waste)	83%	71%
Percentage reserved for beneficial domestic use	17%	29%

* Reference 69, p. 26.
† Liters per capita per day.
‡ Thousands.

It will be noted from the above example that domestic beneficial water requirements are 72% greater in City B than in City A (4300/2500).

It is probable that, in the absence both of metering and of a water rate schedule for metered customers that is high enough to restrain nonbeneficial consumption, either of these cities might have intermittent delivery in the distribution system. However, in the presence of these factors restraining water consumption, continuous delivery would be expected in City B (75% connected) but not in City A (5% connected). (It is noted that apart from some coin-operated devices--kiosks, public fountains, stand-posts--water from public hydrants is almost always provided free, and the flow is often continuous while there is water in the street mains, either through design or in spite of it.)

The situation is well summed up in the following excerpts from a report on Indian national water supply and sanitation schemes:*

A per capita supply varying from 10 gallons to 50 gallons per day is being assumed in the preparation of urban water supply schemes, the figures varying from State to State. In many cases, sufficient note is not taken of the fact that a part of the population served cannot and does not take house connexions, and draws its requirements from public stand-posts only. The total capacity of the schemes is usually based on a future population drawing the supply at the assumed per capita rate uniformly This tends to push up the cost of the scheme on components which are over-sized for the actual requirements now and for several years hence. A greater attention is called for in order to limit the size of the schemes to the paying capacity of the consumers with provisions for a progressive expansion in successive stages, to suit the increasing demand so that the financing of the scheme may be made more viable.

There is a wide variation in labor and material components and their share in various parts of a water supply system. The following figures illustrate how expenditure in 1952 for construction of new water supply distribution systems in the United States varied as a composite average and in percent.†

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* Government of India, Planning Commission, Committee on Plan Projects, Report on National Water Supply and Sanitation Schemes, New Delhi, 1961, p. 11.

† Reference 74, p. 10. See also U.S. Dept. of Commerce, Business and Defense Services Administration, Distribution of the Dollar Expenditure for Water and Sewage Works - New Construction 1952, Business Service Service Bulletin No. 55, by W. L. Picton, August 1954, 4 pp.

	Treatment Plants	Distribution Other Items	Total
Labor	28.0%	27.1%	27.2%
Overhead, profit, equipment charges	15.2	16.6	16.4
Supplies	2.0	1.6	1.7
Machinery and equipment	29.7	9.1	11.6
Other materials	25.1	45.6	43.1
Total	100.0%	100.0%	100.0%

A breakdown of costs for water systems built in Colombia shows the labor share as 25 percent, materials 70 percent, and transportation 5 percent.*

In semiarid or arid areas of developing countries, ground water is usually the predominant source of water supply. Costs† of ground water range from US$0.01 to US$0.10 per 1,000 gallons. In Chile, an official study found that the cost per 1,000 gallons of water ranged from less than US$0.01 for a well with a capacity of 1,585 gallons per minute and only 66 feet deep to US$0.08 per 1,000 gallons for a well with a capacity of only 79 gallons per minute and 328 feet deep. In Taiwan, a project provides for the construction of 250 wells, 200 to 500 feet deep, yielding 500 to 2,000 gallons per minute. The average cost for water from the well field is US$0.02 per 1,000 gallons. Ground water costs are similar in California, these costs vary from US$0.027 per 1,000 gallons to US$0.059 for depths of wells ranging from 150 feet to 350 feet.

Costs associated with several gravel packed wells in the United States provide additional comparative data for ground water supplies (Table 15).

When considering economies of scale for water systems, it must be recognized that analysis of any one element for scale does not necessarily give scale to the composite of several elements or the total system. It is nevertheless essential to gain a grasp of size versus cost for each principal element in order to understand their interrelations, and so gain perspective on overall scale effects. The principal system element exhibiting scale economies in north Indian cities is overhead storage tanks, of reinforced cement concrete. Cost data on tanks of identical construction elsewhere are not available, but a basis for indirect comparison is set below by analysis of scale economies of U.S. elevated steel tanks and ground level concrete tanks.

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* Edmund G. Wagner and J. N. Lanoix, Water Supply for Rural Areas and Small Communities, World Health Organization, Palais des Nations, Geneva, 1959, p. 31.

† Joseph Barnea, "Water Costs in Developing Countries," Development Digest, Vol. IV, No. 1, April 1966, pp. 101-108.

Table 15

SPECIFICATIONS AND COSTS FOR GRAVEL PACKED WELLS AT DIFFERENT SITES
United States

Specifications	Quantities				
Size of outer casing (in.)	24	20	24	16	18
Size of inner casing (in.)	10	12	18	10	12
Depth of well (ft)	170	125	80	140	145
Yield (gal per min)	700	750	500	500	700
Head of pump (ft)	350	150	180	140	210
Capacity of pump (gal per min)	700	750	500	500	700

Costs	Amounts in Dollars				
Cost of well	$16,000	$ --	$ 8,230	$5,960	$ 9,428
Cost of pump	3,500	--	2,875	3,354	5,741
Total cost	$19,500	$11,050	$11,105	$9,314	$15,169
Total cost expressed in October 1954 prices	23,600	13,000	23,100	11,300	15,200
Cost per 100 gallons-per-minute yield as of October 1954	3,370	1,740	4,620	2,260	2,160

Source: United Nations, Department of Economic and Social Affairs, Water for Industrial Use, New York, 1958, p. 38.

Construction costs of the two types of tank as related to holding capacity are shown in Tables 16 and 17. It will be seen that unit costs decrease substantially with increases in tank size. For ground concrete tanks, unit costs decrease 25-27 percent with doubling of capacity in the range from 50,000-150,000 gallons, 20-25 percent in the range to 1 million gallons, and 16 percent from 1 to 2 million gallons. Unit costs for elevated steel tanks decrease 26-28 percent with doubling of capacity in the range from 50,000-300,000 gallons, and 18 percent from 250,000 to 500,000 gallons.

For ground concrete tanks, a least-squares curve fit results in a power function with the equation.*

$$\text{Average Cost} = 1{,}097\ (\text{Capacity})^{-.38}$$

The decrease in unit costs for elevated steel tanks is better described by a hyperbolic function:

$$\text{Average Cost} = .158 + \frac{20.6}{\text{Capacity}}$$

A power function with scale exponent of -.46 also gives a close fit†. As elsewhere when warranted by the statistical analysis, we cite the power function as a means of direct comparison of the scale exponents, which indicate the steepness of decline in unit costs. These substantial negative scale coefficients for U.S. tanks are compared with results from Indian data later in this section.

Interacting effects of scale as a factor in design capacity and growth rate of demand are illustrated by water treatment plants. Probable boundaries of scale economies in construction of water treatment plants are suggested by three reports:

1. An engineering report on Calcutta's water supply master plan[71] presents a cost estimate, reproduced in Figure 3, as a straight line logarithmic plot for plants ranging from one million to 100 million gallons capacity, including prechlorination, flocculation, sedimentation, sand filtration, and post chlorination. Converted to average cost, the implied scale exponent is -.14.

2. More substantial scale effects are indicated by a scale exponent of -.33 for unit costs in an analysis of construction costs of 32 treatment plants in California containing all of the above treatment functions.‡ Costs of land, special foundations, intake

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* R^2 = .990, with deviations of less than 4 percent between calculated and actual costs, except for the smallest and largest tanks, which show deviations of 11 and 7.8 percent, respectively.

† For the hyperbolic function, R^2 = .994, the maximum difference between calculated and actual costs is 4.3 percent. The power function results in R^2 = .969.

‡ Gerald T. Orlob and Marvin R. Lindorf, "Cost of Water Treatment in California," Journal of American Water Works Association, Vol. 50, No. 1, January 1958, pp. 45-55.

Table 16

CONSTRUCTION COSTS OF ELEVATED WATER STORAGE TANKS*
United States, 1961

Capacity (000 gal)	Height 82 feet†			Height 130 feet†		
	Total Cost ($)	Unit Cost ($/gal)	Percentage Relative to Lowest Unit Cost (%)	Total Cost ($)	Unit Cost ($/gal)	Percentage Relative to Lowest Unit Cost (%)
50	$28,900	$0.578	293%	$32,260	$0.645	315%
75	31,050	.414	210	35,200	.469	229
100	36,000	.360	183	40,307	.404	197
125	41,250	.330	168	n.a.	n.a.	n.a.
150	56,200	.308	156	50,970	.340	166
200	52,600	.263	134	57,350	.287	140
250	59,750	.239	121	64,750	.259	126
300	67,600	.225	114	72,040	.240	117
500	98,500	.197	100	102,280	.205	100

n.a. = not available.

* Double ellipsoidal steel tanks with tower supports, foundations, and tank accessories. Cathodic protection and cost of valve pit, valve, heating equipment, and piping not included.

† Elevation from ground to bottom of tank.

Source: U.S. Dept. of Navy, Design Manual: Cost Data for Military Construction, 1961, pp. 482-483.

Table 17

CONSTRUCTION COSTS OF GROUND CONCRETE WATER STORAGE TANKS*
United States, 1961

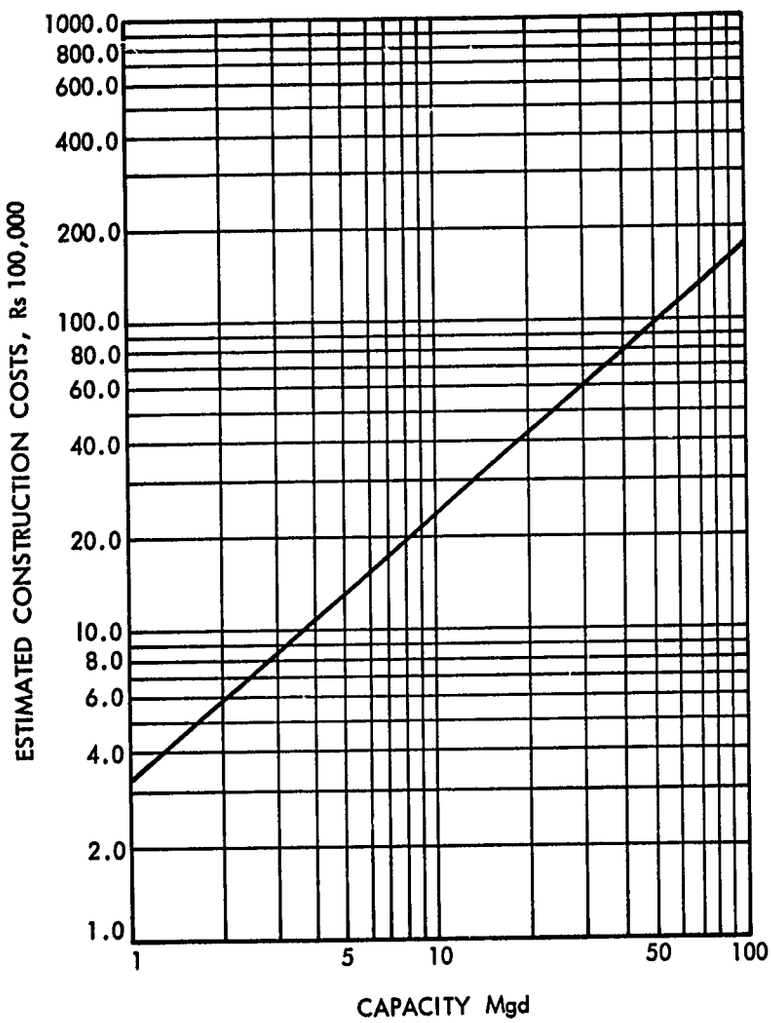
Capacity (000 gal)	Total Cost ($)	Unit Cost ($/gal)	Percentage Relative to Lowest Unit Cost (%)
50	$ 14,000	$0.280	412%
75	16,500	.220	324
100	19,000	.190	279
125	21,500	.172	253
150	24,000	.160	235
250	34,500	.138	203
300	38,400	.128	188
350	41,650	.119	175
400	45,200	.113	166
450	48,600	.108	159
500	52,000	.104	153
750	66,750	.089	131
1,000	81,000	.081	119
1,500	108,000	.072	106
2,000	136,000	.068	100

* Costs are in-place costs for tanks on normal foundations and do not include piping and pumping.

Source: U.S. Dept. of Air Force, Military Construction Pricing Guide, March 1966, p. 26.

Figure 3

ESTIMATED CONSTRUCTION COST FOR WATER TREATMENT PLANTS, CALCUTTA



NOTE: Treatment plant costs provide for prechlorination, flocculation, sedimentation, sand filtration and post chlorination. Costs of land, special foundations, intake jetties, intake pumps, high lift pumps, and engineering and contingencies are not included.

SOURCE: Calcutta Metropolitan Planning Organization, Master Plan for Water Supply, Sewerage and Drainage, Calcutta Metropolitan District (1966-2001), report by engineering consortium, Metcalf & Eddy Ltd. and Engineering-Science Inc., December 1966.

jetties and pumps, high lift pumps, engineering, and contingencies are excluded from the Calcutta estimate. It is not known whether the California analysis includes some or all of these cost elements, which could contribute to the difference in scale effects.

3. Complete water pumping and treatment plants exhibit even sharper scale economies in U.S. cost reports.* For complete plants of five different sizes, ranging from 200,000 to 6 million gallons, a scale exponent of -.70 for average costs is estimated for a curve with close least-squares fit (R^2 =.987).† It would appear that the cost of pumping equipment, although increasing the absolute cost of the plant, rises far less than expected in proportion to capacity and thereby contributes to greater economies of scale.

The analysis of California water treatment costs covers operating and maintenance costs, defined to include labor, chemicals, power, and plant overhead but not the cost of raw water.‡ Operation and maintenance costs are expressed as a power function of average daily flow, the scale exponent being -.41. Scale effects in operating costs (-.41) are thus more substantial than in construction costs (-.33) for these 32 California treatment plants. The authors determine the unit cost of capital recovery through an expression for equivalent daily water production,§ and conclude, for the conditions studied, that the average cost of treatment in a 10-mgd plant is $60 per million gallons, composed of $30.60 operation and maintenance costs and $29.20 capital costs. The resulting cost curve, Figure 4, reveals the interacting effects of scale (design capacity), initial flow level as a ratio to capacity, and the capital recovery period.

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* U.S. Dept. of the Navy, Design Manual: Costs Data for Military Construction, 1961, p. 479.

† The hyperbolic function, with costs decreasing at a gradually decreasing rate, provides a slightly closer fit, with R^2 = .999.

‡ Orlob and Lindorf, op.cit., pp. 48-49.

§ Ibid., pp. 49-50. Taking Q_o as the initial operating flow of a new plant, Q_n as the design capacity to be reached in n years, R as the growth ratio Q_o/Q_n, and Q_e as the equivalent daily water production,

$$Q_e = \left[R + (1-R)\left(\frac{1}{n} + \frac{1}{ni} - \frac{F-i}{i}\right)\right] Q_n$$

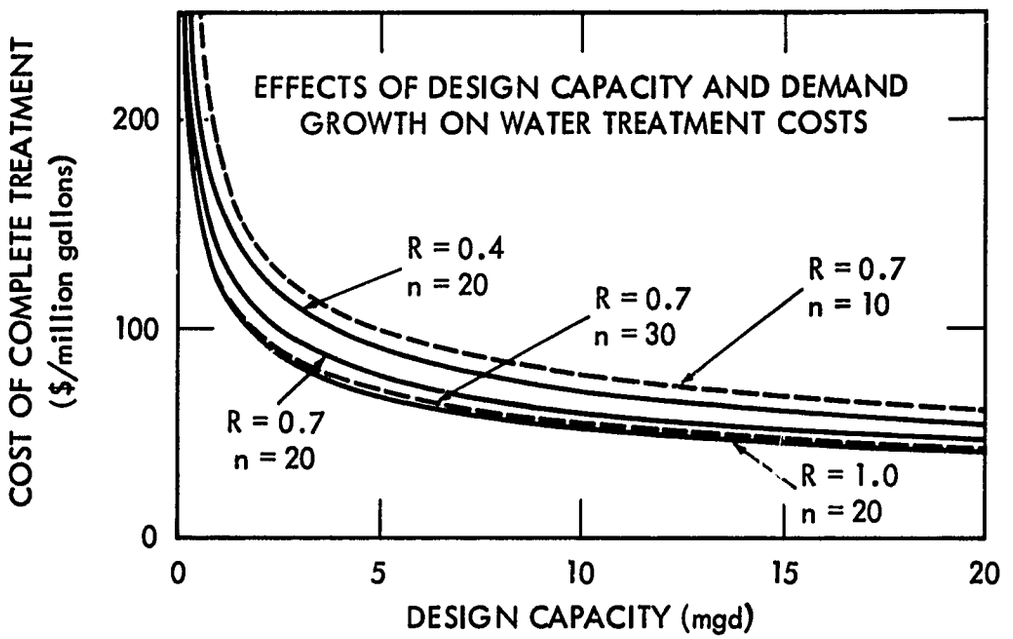
where F is the capital recovery factor based on an interest rate i over a recovery period of n years. The cost of capital recovery in dollars per million gallons is

$$C_r = 704_{Qn}^{-.33}\left[\frac{F}{Q_e/Q_n}\right]$$

Orlob and Lindorf note that the assumption that Q_e is the simple average of Q_o and Q_n would result in underestimation of the unit cost of capital recovery.

Figure 4

EFFECTS OF DESIGN CAPACITY AND DEMAND GROWTH ON WATER TREATMENT COSTS



Curves are plotted from cost functions cited on page 89, with R as the growth ratio Q_o/Q_n (footnote 4, page 91), n as the capital recovery period in years, and i, the interest rate, at 5 percent. Solid curves indicate the effect of a changing R, dashed curves the effect of a changing n.

Source. Gerald T. Orlob and Marvin R. Lindorf, "Cost of Water Treatment in California," Journal of American Water Works Association, Vol. 50, No. 1, January 1958.

It is evident that decreasing unit construction costs with increases in capacity are characteristic of water treatment plants, reported scale exponents ranging from a low -.14 to a substantial -.33 for plants excluding pumping equipment. Established plants realize higher economies of scale in operating costs. While local conditions may outweigh scale effects in determining cost variations, the scale factor is clearly of major significance in this component of water supply systems.

Analysis of India Field Data. In the study region, the chief source of water is underground water. The region, in the Indo-Gangetic plain, has a thick cover of alluvium of 250 to 300 feet depth serving as an excellent subsurface reservoir. One estimate by the Uttar Pradesh Irrigation Department* on yields by subsurface reservoirs puts it at 1.25 cusecs per square mile in the study areas of Uttar Pradesh. The geological conditions in the selected study region are more or less similar and the yield generally varies from 0.9 cusecs to 1.25 cusecs per square mile.

Even in cities like Kanpur and Varanasi where there is river water use, the new and outlying areas use the underground source as well. The discussion in this section is mainly of water supply system from underground water source. The main components are the tubewell, pumping plant, the distribution network, and overhead tanks (which mainly function as standby reservoirs from which to draw supply during emergency or slack pumping periods).

Tubewells. The installation of a tubewell is specialized civil engineering work, and in the study region the drilling of a bore hole is mostly by rotary drills which are transported to site. The major operational steps in the construction of tubewells are: (1) drilling of borehole, (2) lowering of tubewell assembly (TWA),† and (3) developing and testing.‡

In public water supply systems, generally tubewell installations are done departmentally by the Public Health Engineering Department§ or by private firms. Field study observations indicate that the cost of installation of tubewells is governed by many variables but chiefly by the depth of boring and the type of aquifer met with at site. The latter dictates not only the depth of bore but also the length and type of TWA and the developing time for the tubewell.

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* S. R. Aggarwal, Drinking Water Supply by Tube-Wells, Local Self Government Engineering Department, Uttar Pradesh Government, Kanpur, 1967, unpublished.

† The term "tubewell assembly" (TWA) normally includes the outer casing pipe (housing pipe), inner casing pipe (slotted and blind pipes), centering devices, and other accessories.

‡ Developing and testing is the process of creating a condition around the screen (slotted pipes) for the water to flow in with minimum friction and contamination from the drilling that has been made.

§ In Uttar Pradesh by the Local Self Government Engineering Department.

Since the type of strata and the depth are indeterminate until the completion of tubewell installation at the site, there is always variation between actual cost and estimated cost of a tubewell. Because of this peculiar feature, the costing of tubewell is a special phenomenon. A marginal cushion is always provided for in the estimated cost for variations in the depths of aquifer met and in the developing time. In practice, the unit cost for tubewell is quoted on the basis of per foot depth for a type of combination of housing and slotted pipes.

Table 18 shows the unit cost (rupees per running foot) of tubewells in depth ranges from 300 to 600 feet.

Table 18

UNIT COST OF TUBEWELL,* 1967
(Rs. per Rft)

Depth	Cost for TWA Combinations†				
	27/18/12	27/18/10	27/15/8	27/15/6	24/15/8
Up to 300 ft BGL‡	123	113	102	100	97
Up to 400 ft BGL	117	107	94	95	91
Up to 500 ft BGL	115	104	94	92	88
Up to 600 ft BGL	114	103	93	90	86

* Quotation rates applicable to cities in the study area.
† TWA combination: diameter in inches for bore hole/housing pipe/slotted pipe (e.g., 27/18/12).
‡ BGL: below ground level.

Source: Field study.

Of the total cost of the tubewell combination 27/15/8, nearly 11 percent is for labor, 67 percent is for materials, and 22 percent is for other charges including drilling rig and overheads. Table 19 provides a detailed cost breakdown.

Table 19

COST BREAKDOWN OF TUBEWELL
(TWA 27/15/8)
Depth - 300 feet

Cost Items	Rupees
Boring of 27" diameter hole	8,100
Housing pipe (15" diameter)	4,600
Slotted pipe (8" diameter)	2,400
Blind pipe (8" diameter)	2,640
TWA auxiliaries	500
Lowering of TWA	550
Gravel	2,820
Developing and testing	2,250
Transportation of rig	1,750
Overhead	5,016
Total	30,626
Average per Rft	102

Source: Field study.

Pumping Machinery. Pumps lift water by generating a potential vacuum which permits the atmospheric pressure to force water up the suction pipe. Generally, centrifugal pumps are used for lifts up to 20 feet. For tubewells where water is more than 20 feet below ground level, deepwell turbine pumps are used. The vertical shaft is located in the housing pipe section and only the motor is located at ground level.

The capacity of the pump is a function of "lift head,"* and the discharge required. The cost of pumping machinery is reckoned by the discharge and the lift head. Table 20 indicates the cost for different discharge and lift head combinations.

* Lift head is the height between the minimum depression head (BGL) which is allowed in the tubewell, and the staging height above ground level (AGL). In the study region, depression head generally varies from 16 to 25 feet, with the first water level BGL at 25 to 30 feet. In practice (for Uttar Pradesh only), tubewells are designed from an average depression head of 16-25 feet BGL.

Table 20

COST OF PUMPING MACHINERY AT DIFFERENT DISCHARGES AND LIFT HEADS

Discharge (gal/hr)	Lift Head (ft)	Cost* (Rs.)
21,000-33,000	43-58	13,000
27,500-40,000	60-75	15,000
25,000-36,000	85-132	18,000
39,000-54,000	75-135	22,000

* Based on Delhi, 1967.

Source: Field study.

Distribution Costs. Distribution costs are more difficult to quantify since the sizes and lengths of the pipes are determined to fit specific needs. The function of any system and the flow rates required also influence the final costs and geometric patterns of distribution systems. However, general cost information for distribution systems is appropriate, because this information can be employed with engineering judgment and modified for specific situations to arrive at cost estimates within an acceptable range of error.

Most of the field data collected in this category were not comparable because of a variety of variables in each situation. However, with the use of the data collected on labor and material components, an attempt is made to estimate distribution costs per acre served. A study of distribution systems in areas ranging from 35 acres to 225 acres results in Table 21 for industrial areas and Table 22 for residential areas.

Overhead Water Tanks. The principal material used for overhead tanks in the region is reinforced cement concrete (RCC); therefore, the discussion will be focused on this type only. The construction of RCC overhead tanks (OHT) is one of the specialized civil engineering skills, and in the field region, it is done by specialized agencies. The major components of OHT are (a) tank, (b) staging columns, and (c) foundation. The shape of the tank varies for different sizes. The prevalent practice in the region is to use a square tank for capacities of 250,000 gallons and above; a circular tank with domed top and bottom and conical wall

Table 21

COST OF DISTRIBUTION PIPELINE PER ACRE--INDUSTRIAL AREA

Diameter of Pipe* (in.)	Cost of Pipe Unit† (Rs./Rft)	Rs.
12	25	350
6	12	300
4	10	200
3	6	60
2-1/2	3	50
Subtotal		960
Auxiliaries @ 10%		96
Specials @ 10%		106
Subtotal		1,162
Overhead @ 15%		174
Total		1,336
Equivalent length of 6" pipe		111 ft

Note: Designed for industrial area, density 50 workers per acre, 30 gpd per worker. Terminal pressure - 35 lb.

* Cast iron pipes with tryton or SS joints.
† Delhi, 1967.

Source: Field survey.

Table 22

COST OF DISTRIBUTION PIPELINE PER ACRE--HOUSING AREA

Diameter of Pipe* (in.)	Cost of Pipe	
	Unit† (Rs./Rft)	Rs.
5	7.70	269.5
4	6.30	239.4
3	5.10	178.5
2-1/2	4.40	154.0
2	3.66	530.7
1-1/2	3.04	182.4
Subtotal		1,554.5
Auxiliaries @ 10%		155.5
Specials @ 10%		171.0
Subtotal		1,881.0
Overheads @ 15%		282.0
Total		2,163.0
Equivalent length of 2" pipe		591 ft

Note: Designed for housing area, density 30 dwellings per acre, 30 gpcd.

* Pipes 3" and below are GI pipes.
† Delhi, 1967.

Source: Field survey.

(Intze type) for capacities of 200,000, 150,000, and 100,000 gallons; and a circular tank with domed top and bottom for a capacity of 50,000 gallons.*

The tank portion costs more than half of the total cost (54-56 percent), staging columns cost 22-25 percent, and the foundation costs 19-24 percent (Table 23).

Table 23

COST COMPONENTS OF REINFORCED CEMENT CONCRETE OVERHEAD TANKS*

Capacity (000 gal)	Cost Components (percent)		
	Tank	Staging Columns	Foundation
300	55%	24%	21%
250	55	25	20
200	54	22	24
150	55	22	23
100	55	25	20
50	56	25	19

* Staging height 50 ft., safe bearing capacity of soil 0.75 tons per sq ft.

Source: Ganon Dunkerley & Co. Ltd., New Delhi.

For cost comparisons, the major components of construction materials and labor were selected for an OHT of 150,000 gallons capacity at 50 feet staging height. Total requirements for each item were multiplied by the relevant price for each city and year to establish OHT cost indexes (Table 24). For the specified 150,000 gallon, 50 foot tank, the percentage cost of each building element for Bareilly in the base year 1965 was as follows on page 101.

* Information from Ganon Dunkerly & Co. Ltd., New Delhi, a private company specializing in OHT construction. The majority of the OHTs in the study region are constructed by this firm.

Table 24

CONSTRUCTION COST INDEX FOR OVERHEAD WATER TANKS
18 Cities, 1962-67
(Bareilly 1965 = 100)

State and City	1962	1963	1964	1965	1966	1967
Punjab						
Jullundur	91	92	93	96	107	114
Phagwara	90	92	96	103	112	120
Ludhiana	87	91	96	100	111	117
Patiala	81	83	86	92	99	107
Haryana						
Ambala	87	89	92	98	107	112
Jagadhri-Yamunanagar	87	90	92	99	107	114
Karnal	87	89	92	98	106	113
Bhiwani	88	91	94	101	109	114
Uttar Pradesh						
Saharanpur	81	83	86	92	94	100
Modinagar	82	85	89	95	101	110
Hapur	92	95	98	104	111	123
Amroha	84	87	92	98	104	113
Bareilly	86	90	93	100	107	116
Kanpur	91	95	98	104	108	116
Faizabad	88	92	96	102	109	122
Gorakhpur	94	98	103	111	116	126
Maunath Bhanjan	98	102	107	115	120	136
Varanasi	86	88	92	99	107	116

	Percent
Cement	19%
Mild steel	33
Timber	10
Coarse sand	6
Aggregate II	10
Ballies (beams)	4
Labor*	18

A major cost variable for overhead tanks is the bearing capacity of the soil. As shown in Table 25, foundation costs increase rapidly for decreases in safe bearing capacity (SBC) of soil below 0.75 ton per sq ft, and decrease slowly for any increase in SBC above 0.75 ton per sq ft.†

Table 25

OHT FOUNDATION COSTS IN DIFFERENT SAFE BEARING CAPACITIES
Foundation Cost at 0.75 SBC = 100

SBC (tons per sq ft)	OHT Capacity (000 gallons)		
	200	150	100
1.50	49	47	50
1.00	75	66	68
0.75	100	100	100
0.50	189	174	167

Note: RCC annular raft foundation.

* The labor component includes all categories of labor required in overhead tank construction.

† Based on cost reports of consulting engineer, Ganon Dunkerley & Co. Ltd., New Delhi.

Reported construction costs for OHTs, corrected by cost index for time and place, are shown in Table 26. Unit costs vary from Rs. 3.01 per gallon of capacity to Rs. .93 per gallon, tending to decrease with increases in tank capacity. In a simple regression, the equation of best fit is of the power function form $Y=aX^b$, or for capacity in thousand gallons,*

$$\text{Total Cost} = 3{,}942\ (\text{capacity})^{.75}$$

Construction cost per gallon of capacity is derived by dividing the above equation by capacity, giving

$$\text{Average Cost} = 3{,}942\ (\text{Capacity})^{-.25}$$

Relating total construction cost to capacity and staging height, a multiple regression analysis in logarithms of the variables produces virtually the same R^2(.969) and scale exponent (b_1 = .73), and indicates a low rate of increase in total cost as a function of staging height (b_2 = .16). Calculated unit costs as a function of capacity and staging height are shown in the final columns of Table 26, along with percentage differences between actual and calculated costs. The calculated unit costs are plotted on a logarithmic scale in Figure 5 for several staging heights, for use in cost estimation on incremental infrastructure needs.

The regression line's negative slope of -.27 is well below the scale exponents of -.38 for ground concrete tanks and -.46 for elevated steel tanks reported above for U.S. cost experience. Such contrasts in economies of scale for similar structures of different materials and construction technologies offer useful lines for further research.

Treatment Plants. Ground water when used as the source for a water supply system usually does not require extensive treatment for safe human consumption. Generally, the only treatment is chlorination while water is in storage or prior to delivery to the customer. In the study region, nearly 50 percent of the tubewell supply systems have no chlorinators.

However, in the instance where supply is derived from surface water sources such as rivers and canals (Kanpur, Varanasi, and Bhiwani), complete treatment is provided. Information on treatment plants in these cities was not significant for any comparison with the Calcutta and U.S. cost data reported above.

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* The power function is associated with R^2=.967 and .969 in simple and multiple regressions, respectively, as compared with R^2 = .918 and .931 for the linear function Y = a + bX.

Table 26

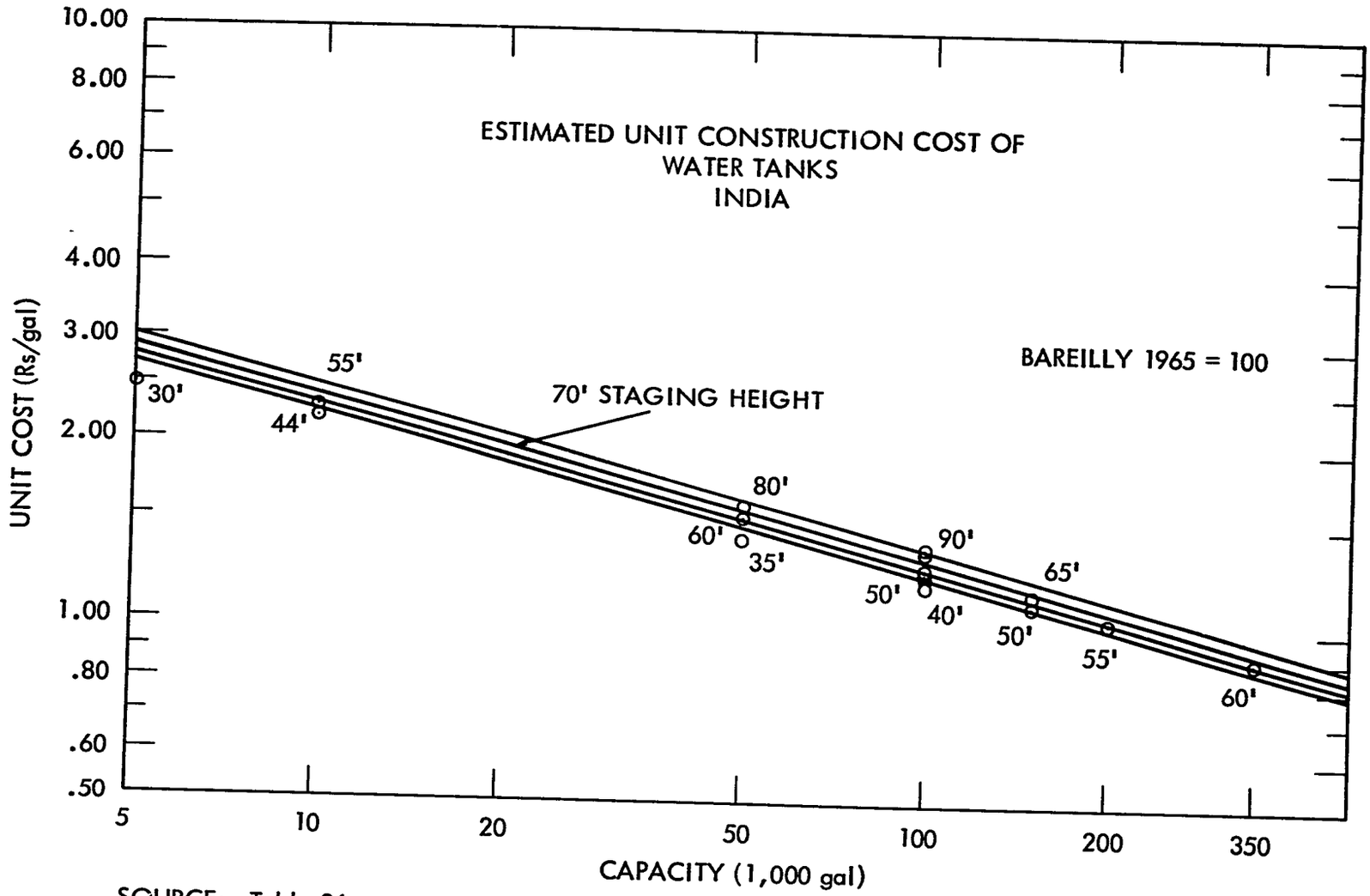
CONSTRUCTION COSTS OF OVFRHEAD WATER TANKS, REINFORCED CEMENT CONCRETE
(Bareilly 1965 = 100)

City	Year Built	Capacity (000 gal)	Staging Height (ft)	Actual* Total Cost (Rs.)	Actual* Unit Cost (Rs./gal)	Calculated† Total Cost (Rs.)	Calculated† Unit Cost (Rs./gal)	Difference: Actual and Calculated Unit Cost (%)
Patiala	1964	5	30	13,313	2.66	12,410	2.48	- 6.8
Ambala	1965	10	44	18,367	1.84	22,000	2.20	+ 19.6
Ambala	1966	10	55	20,629	2.06	22,830	2.28	+ 10.7
Ludhiana	1961	10	55	30,120	3.01	22,830	2.28	- 24.3
Gorakhpur	1963	50	35	68,367	1.37	69,040	1.38	+ 0.7
Gorakhpur	1967	50	60	59,127	1.18	75,515	1.51	+ 28.0
Jagadhri-Yamunanagar	1965	50	80	76,768	1.54	79,220	1.58	+ 2.6
Jullundur	1960	100	40	119,048	1.19	117,400	1.17	- 1.7
Gorakhpur	1963	100	45	122,449	1.22	119,800	1.20	- 1.6
Ambala	1961	100	50	128,400	1.28	121,900	1.22	- 4.7
Maunath Bhanjan	1961	100	55	127,660	1.28	123,800	1.24	- 3.1
Patiala	1964	100	85	203,469	2.03	133,100	1.33	- 34.5
Jullundur	1962	100	90	104,000	1.04	134,400	1.34	+ 28.8
Gorakhpur	1963	150	50	163,265	1.09	164,100	1.09	0
Hapur	1966	150	65	155,856	1.04	171,500	1.14	+ 9.6
Saharanpur	1960	200	54	213,919	1.07	205,400	1.03	- 3.7
Gorakhpur	1963	200	55	198,980	0.99	206,000	1.03	+ 4.0
Bareilly	1965	350	60	325,000	0.93	315,200	0.90	- 3.2

* Adjusted to Bareilly 1965 = 100.
† Computed by regression equation as explained on p. 102.

Figure 5

ESTIMATED UNIT CONSTRUCTION COST OF WATER TANKS, INDIA



SOURCE: Table 26.

Annual Maintenance and Operation Costs (AMO). A primary factor to reckon in AMO costs is the method by which water is supplied to the consumer. The consumption pattern varies according to the type of supply to the consumer, i.e., whether by public standposts* or by on-site house connection, unmetered or metered supply. In the majority of the cases in the region, there is a combination of public standposts and house connections. Generally, the emphasis is to provide more standposts initially and gradually increase house connections and metering of individual supply in that order. It is difficult to categorize these situations for any comparative analyses.

In a water supply system from a ground water source, the majority of AMO costs stem from three main categories:

1. Power for driving the pumping plant

2. Personnel for maintenance and operation of pumping plant and distribution system

3. Repairs and replacements in both

In this section, AMO costs are analyzed mainly in two categories: (1) per production and delivery of 1,000 gallons of water, and (2) per capita of served population, in order to gain a sufficient measure of scale for further cost estimates to be used in subsequent chapters. Unit costs in the two categories express themselves as scale functions, other things being equal in the different systems considered. Table 27 amplifies this further. Although the data are limited, the following conclusions emerge:

1. The AMO cost per capita tends to decrease as the population served increases. This is expected.

2. The AMO cost of supplying 1,000 gallons tends to decrease as the capacity of supply† increases.

Plotting the relevant cost points by increase in supply capacity (Figure 6), it is observed that the unit cost varies from the high 0.60 to the low 0.18 for the corresponding increase in mgd from 0.6 to 3.2. Despite the spotty data, the trend is perceptible. The cost line graphed in Figure 6 is used in future calculations of AMO cost for supply capacities within the 0.6 to 3.2 mgd range.

Annual Cost. By far the most difficult information to obtain in cost studies of water supply is the life of the total system. For the study region, where tubewell supply is most common, adequate data on the

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* Generally, public fountains are referred to as public standposts or public hydrants.

† Here the capacity is the production and delivery of the daily requirements, i.e., the consumption in mgd.

Table 27

ANNUAL MAINTENANCE AND OPERATION COSTS OF WATER SYSTEMS*
Selected Indian Cities
1967

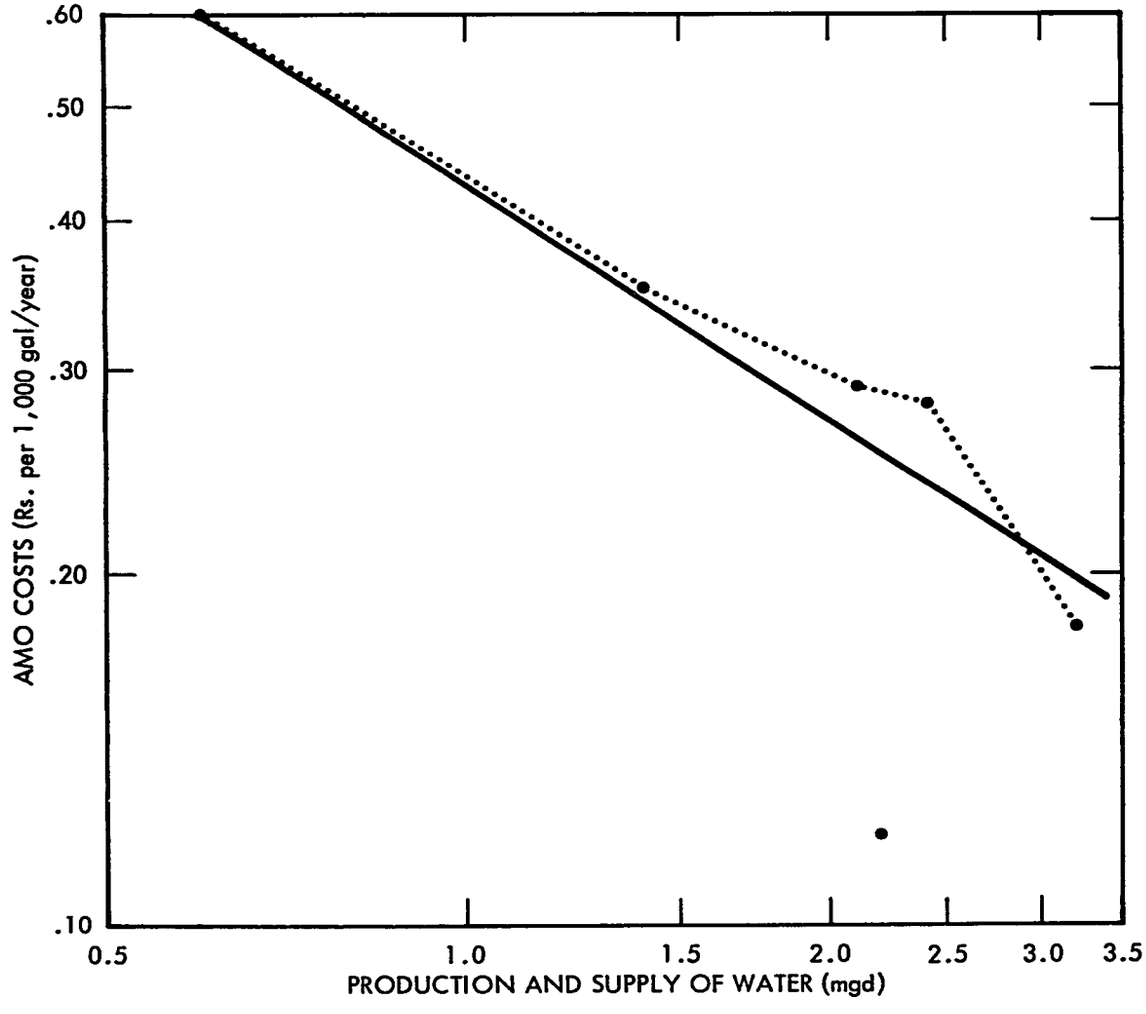
City	Population Served (000)	Daily Consumption (mgd)†	AMO Costs (Rs.)		
			Total	Per Capita	Per 1,000 gal/year
Phagwara	4	0.1	9,700	2.43	0.27
Karnal	9	n.a.	36,000	4.00	n.a.
Jagadhri	21	n.a.	27,183	1.29	n.a.
Hapur	62	0.6‡	130,635	2.11	0.60
Ambala Cant.	70	1.4	179,200	2.56	0.35
Ambala City	85	2.4	249,121	2.93	0.28
Saharanpur	130	2.2	94,313§	0.73	0.12
Gorakhpur	223	3.2	207,414	0.93	0.18
Bareilly	250	2.1	223,496	0.89	0.29

n.a. = not available.

* Ground water source.
† Million gallons per day.
‡ For 1965.
§ From local authorities.

Figure 6

ANNUAL MAINTENANCE AND OPERATION COSTS OF WATER SUPPLY



SOURCE: Table 27.

average life of whole systems are not available. In estimating annual capital cost, therefore, systems costs must be assigned to their principal components. Based on public utilities commission experience, physical lives are assumed as follows:

	Years
Tubewells	30
Overhead tanks	65
Mains, cast iron	50
Pumps	25

Sewage and Industrial Waste

Availability of a potable water supply is probably the greatest need felt by the world's significant population centers, and along with this, the disposal of used water containing human, household, and industrial wastes. These wastes are called sewage and the sewer is the pipe or conduit used for carrying the sewage, sewerage refers to the whole sewer/sewage system. Sewage contains a small amount of solids in proportion to the tremendous weight of water needed to carry it. In normal domestic sewage, generally more than one ton* of water is required to carry one pound of solids, half of which is in solution, one quarter in suspension, and one quarter tending to settle and drift in the direction of water flow.

Cost Factors in Sewerage System Components. The extent to which sewage is conveyed from its source, treated and ultimately disposed of depends on the costs for the necessary facilities and the ability of the population center to pay for them. Sanitary sewage and industrial waste are derived largely from the water supply. What proportion of water consumed will reach the sewer depends on local conditions.† Adequacy of sewer size, method of collection, treatment, and disposal are dependent on socioeconomic factors and availability of water supply for drinking and other purposes. Other factors to reckon with are the slope of sewers and the amount of precipitation and storm water that infiltrate or are allowed to collect in the system.

Broadly, a sewerage system is divided into collection, treatment, and disposal categories. The principal cost elements for simpler systems are labor costs in the laying of pipes, mains, and drains; and costs of pipe and pumps. For the more complicated sewage treatment plants, the plant equipment itself and costs of skilled operators become important. In complete systems, treatment plants form the largest element in total costs.

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* Reference 68, p. 5.

† Steel, op. cit., p. 19; "Although sewage may vary in individual cities from 70 to 130 percent of the water consumed, designers frequently assume that the average flow, including a moderate allowance for filtration, equals the average rate of water consumption."

Once it is recognized that sewers are inevitable in urban areas, the question is when in time (at what stage) sewers will be used and what will be the alternatives available for an economic system. A study of San Francisco Bay Area communities* shows that of the three alternatives shown in Figure 7, "dry sewers are more economical if a conversion to sewers is to take place within the first four years. After four years it becomes more economical to install septic tanks initially and to put in the more expensive sewers at a later date. This four-year break-even point is based on only tangible economic costs and makes no allowance for the cost of disturbance and damage to the appearance of neighborhood with the streets and sidewalks being torn up to permit the later addition of sewers." The comparison is based on computation of the present worth of future costs at an 8 percent discount rate. The analysis shows the decision to be somewhat sensitive to a change in discount rate to 5 percent, but not materially to a change to 10 percent.

The costs of sewer lines indicate an economy of scale since as diameter increases, the cost per gallon of sewage passing a given point in the lines decreases. A 36-inch sewer costs somewhat less than twice what an 18-inch sewer costs, yet it is able to transport approximately four times as much sewage.† However, the degree to which this affects unit costs depends heavily on other design factors, including the volume and type of sewage carried and the density and layout of collection area, whether industrial, residential, or other use.

Individual industries which have unusually high liquid waste disposal requirements may overextend the capacity of municipal systems not geared to such loads. In such unique cases, the costs of special sewerage facilities are appropriately borne by the industry concerned.

Sanitary treatment facilities are commonly considered of two types, primary and secondary. Primary plant costs vary with the volume of waste handled, degree of chemical treatment and biological oxygen demand (BOD) reduction in the effluent, as well as the procedure for sludge digestion and disposal. Secondary treatment costs are chiefly influenced by the amount of additional BOD reduction before effluent disposal into stream or body of water. Essentially, secondary treatment plants are an expansion of primary plants by the addition of activated sludge or trickling filter facilities.

A number of cost studies have been made for economies of scale in treatment plants in developed countries, and they clearly suggest that economies of scale are a factor in considerations for size of treatment

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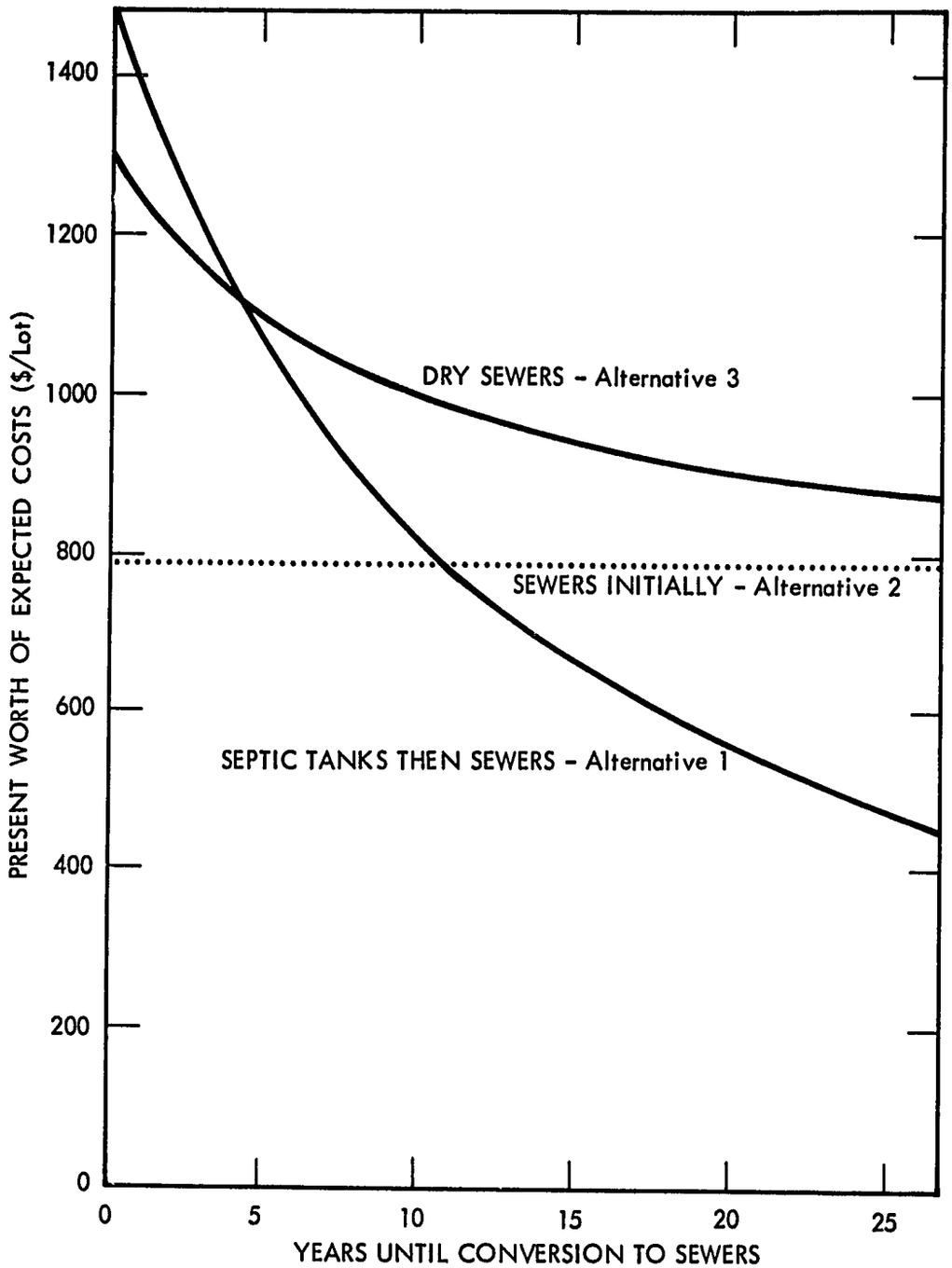
* Carter H. Harrison, Jr., Economic Analysis of Sewage Control for Residential Suburbs, Report EEP-20, Institute in Engineering-Economic Systems, Stanford University, August 1966, p. 57.

† Ibid., p. 41.

Figure 7

COSTS VERSUS TIME-THREE SEWAGE CONTROL ALTERNATIVES



SOURCE: Harrison, Carter H., Jr., Economic Analysis of Sewage Control for Residential Suburbs, Report EEP-20, Institute in Engineering-Economic Systems, Stanford University, August 1966, p. 56.

plant.* Table 28 indicates that the installed cost per capita for sewage treatment plants varies inversely with the population equivalent being served, and cost per gallon per day varies inversely with capacity. Thus economies of scale in first costs can be realized. Three cost curves based on the studies summarized in Table 28 are shown in Figure 8 for reference.† Unit construction costs decrease at a constant logarithmic rate over the range indicated.

Unfortunately, very limited data are available on maintenance and operation costs of a sewerage system as a whole, although cost data for treatment plants are separately available. Annual maintenance and operation costs for primary treatment plants in the United States are summarized on Table 29, while Figure 9 presents a comparison of annual maintenance and operating costs per mgd for four types of treatment. The estimating equations on which these curves are based indicate that the annual cost of operation and maintenance per mgd or per capita decreases at a logarithmically decreasing rate with increasing size of plant.‡§

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* See Engineering News-Record, Vol. 168, No. 12, March 22, 1962, pp. 132-33, for cost curves and estimates for treatment facility costs. Also P. P. Rowan, K. H. Jenkins, and D. W. Butler, "Sewage Treatment Construction Costs," Water Pollution Control Federation Journal, Vol. 32, June 1960, pp. 594-604.

† Rowan, et al., op. cit., pp. 597-601.

‡ P. P. Rowan, K. H. Jenkins, and D. H. Howells, "Estimating Sewage Treatment Plant Operation and Maintenance Costs, "Water Pollution Control Federation Journal, Vol. 33, No. 2, February 1961, pp. 111-121.

§ See also Robert Smith, "Cost of Conventional and Advanced Treatment of Wastewater," Journal of the Water Pollution Control Federation, Vol. 40, No. 9, September 1968, pp. 1,546-1,574.

Table 28

CONSTRUCTION COSTS OF SEWAGE TREATMENT PLANTS--UNITED STATES

Primary Treatment

Pop. Equiv.	Flow (mgd)	Per Capita Cost: Lower Limit ($)	Per Capita Cost: Est. ($)	Per Capita Cost: Upper Limit ($)	Cost per gpd Capacity: Lower Limit ($)	Cost per gpd Capacity: Est. ($)	Cost per gpd Capacity: Upper Limit ($)
100	0.01	$10.49	$15.58	$23.20	$0.1049	$0.1558	$0.2320
1,000	0.1	4.99	7.42	11.05	0.0499	0.0742	0.1105
10,000	1.0	2.38	3.53	5.26	0.0238	0.0353	0.0526
100,000	10.0	1.13	1.68	2.50	0.0113	0.0168	0.0250

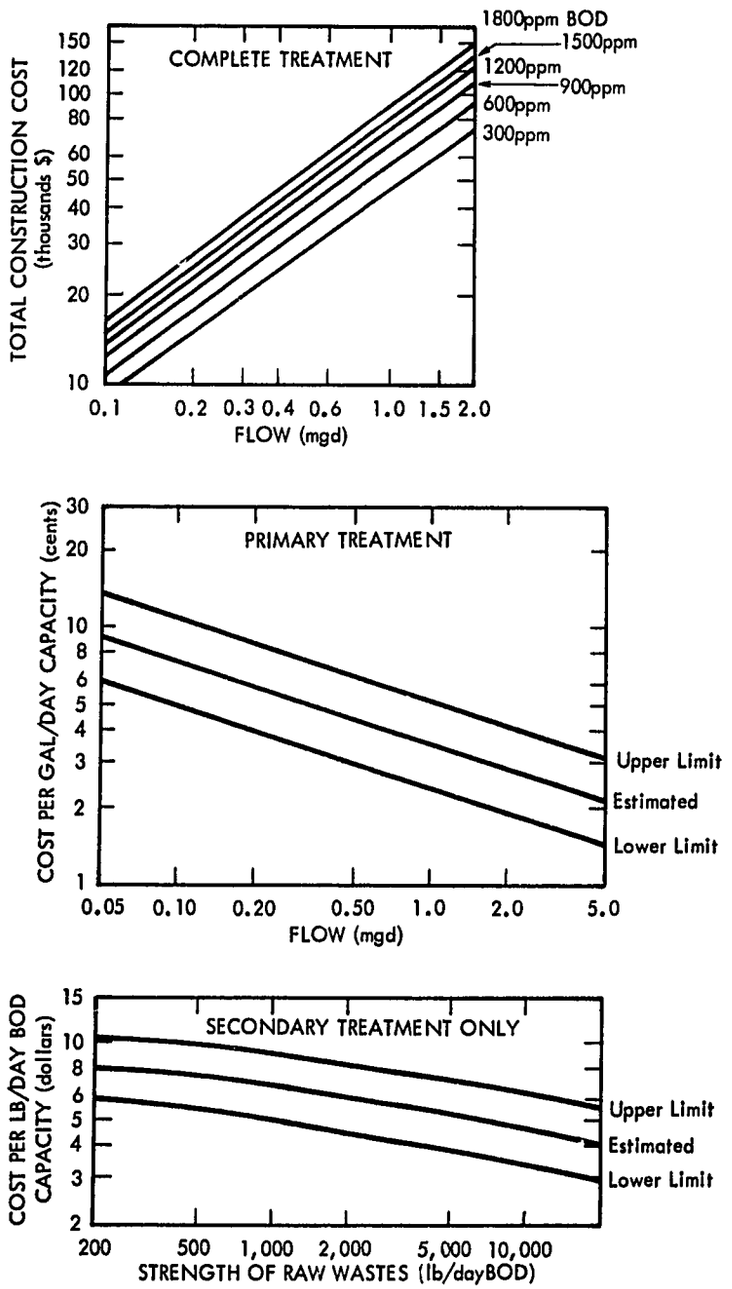
Secondary Treatment Only

Pop. Equiv.	BOD Loading (lb/day)	Per Capita Cost: Lower Limit ($)	Per Capita Cost: Est. ($)	Per Capita Cost: Upper Limit ($)	Cost per lb of BOD: Lower Limit ($)	Cost per lb of BOD: Est. ($)	Cost per lb of BOD: Upper Limit ($)
100	20	$1.31	$1.61	$1.83	$6.55	$8.05	$ 9.15
1,000	200	1.20	1.60	2.08	6.00	8.00	10.40
10,000	2,000	0.87	1.20	1.63	4.35	6.00	8.15
100,000	20,000	0.57	0.80	1.11	2.85	4.00	5.55

Source: Engineering News-Record, Vol. 168, No. 12, March 22, 1962, pp. 132-133.

Figure 8

CONSTRUCTION COSTS OF SEWAGE TREATMENT PLANTS, U.S.



SOURCE: Reprinted from Engineering News-Record, March 22, 1962. Copyright, McGraw-Hill, Inc. All rights reserved.

Table 29

ESTIMATED ANNUAL OPERATION AND
MAINTENANCE COST FOR PRIMARY PLANTS--UNITED STATES

Population Served*	Estimated Annual Cost ($/cap)† Lower Limit‡	Expected Value	Upper Limit§	Average Flow** (mgd)	Estimated Annual Cost ($/mgd)†† Lower Limit‡‡	Expected Value	Upper Limit§§
1,000	$1.86	$2.67	$3.83	0.1	$12,602	$23,294	$43,094
10,000	0.98	1.41	2.02	1.0	5,808	10,736	19,862
100,000	0.63	0.91	1.30	10.0	3,635	6,719	12,430
1,000,000	0.47	0.67	0.96	100.0	2,655	4,908	9,080

* Valid Population range, 1,000 to 500,000.

† Estimating equation

$$\log y = \frac{1}{0.53161 + 0.16975 \log x}.$$

‡ Ratio for lower limit, 0.697.

§ Ratio for upper limit, 1.434.

** Valid flow range, 0.1 to 100 mgd.

†† Estimating equation.

$$\log y = \frac{1}{0.49273 + 0.23867 \log x}.$$

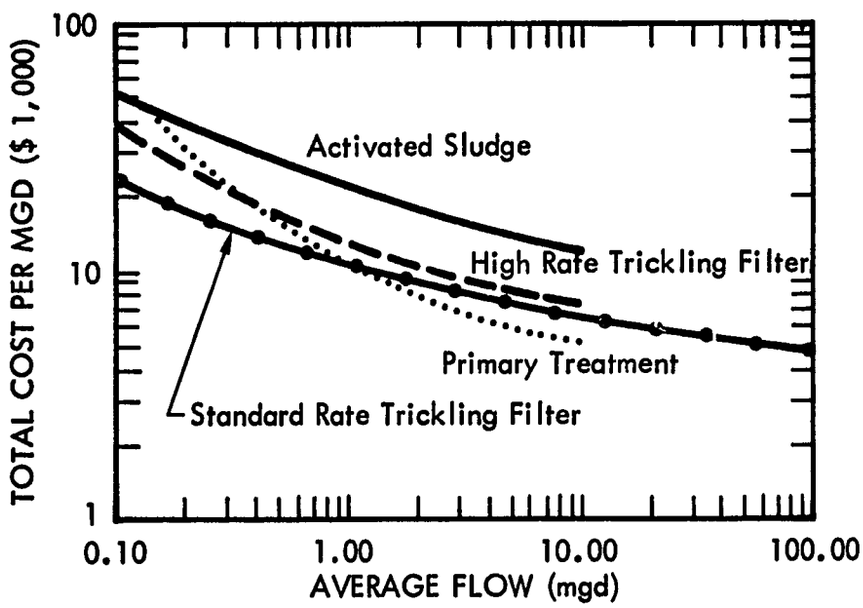
‡‡ Ratio for lower limit, 0.541.

§§ Ratio for upper limit, 1.850.

Source: P. P. Rowan, K. H. Jenkins, and D. H. Howells, "Estimating Sewage Treatment Plant Operation and Maintenance Costs," Water Pollution Control Federation Journal, Vol. 33, No. 2, February 1961, pp. 113, 116.

Figure 9

ANNUAL OPERATION AND MAINTENANCE COSTS FOR FOUR METHODS OF SEWAGE TREATMENT, U.S.



SOURCE: Rowan, P. P., K. H. Jenkins, and D. H. Howells, "Estimating Sewage Treatment Plant Operation and Maintenance Costs," Water Pollution Control Federation Journal, Vol. 33, No. 2, February 1961, p. 120.

Analysis of India Field Data. Data related to sewage collection, treatment, and disposal in the research study area were found to be almost nonexistent or in such a form that very little meaningful cost information could be derived.

Of the 18 cities studied, six had no sewerage system; 11 had sewerage schemes under progress either partially commissioned or not commissioned for use.* In the majority of the cities, it was found that the sewerage scheme proposals were for buried ring sewers to collect sewage from within the heart of the city via open channels, and direct it to disposal areas. The disposal was either into streams or into sewage farms for raising crops. The disposal was without treatment except for dilution and sludge separation at some terminal pumping points.

In many of the cities, various types of sewage disposal for both domestic sewage and industrial wastes were encountered. These varieties existed even within the limits of a single city. Despite the eventual need for modern facilities in the majority of the cities, the use of simpler and less expensive means of sewage disposal was prevalent. The disposal works varied from a mere pump, installed above an oversize manhole, to a screening chamber and collection tank and pumping plant. Many of the manufacturing establishments in the cities took care of their own sewage by septic tanks, by the use of convenient outlets, or by the discharging of wastes into a nearby field or open gutter.

The situation is not common to a developing country alone.† The history of modern sewer systems shows that, as cities grow, rudimentary methods give place to water-carried sewerage systems. The greater safety of sewerage and its convenience and freedom from nuisance cause it to be adopted even in small modern cities whenever finances permit.

Despite the limited data, a discussion is justified to gain insight into sewerage cost characteristics. The general areas of cost for sewerage works are ring mains (sewer lines), laterals, treatment plant, and disposal plant. Within this framework is included the pumping station. No comparable data for a completed city sewerage system are available but the following recent estimates illustrate the major variables and their influence on the orientation of costs in individual situations.

A sewerage scheme prepared for Phagwara in 1963 provided for a population of 29,000 in an area of 650 acres. The proposal was for a ring

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* See review of City Inventory, Chapter V, page 257.

† See reference 68, p. 3. "In 1935 in the U.S.A., 69.5 millions of urban population (91% of the total) were covered by sewerage development; the sewage disposal by dilution covered 41 million urban population and treatment preceding dilution 28.5 million."

sewer, section 24" x 36", to collect sewage from the heart of the city for disposal by the pumping plant to broad irrigation. The estimated components of cost were:

	Rupees	Percent of total Cost
Ring sewer	255,688	53.3%
Pumping plant	61,483	12.8
Laterals	96,180	20.1
Other	66,000	13.8
Total	479,351	100.0%

The estimated unit cost per capita is Rs. 16.53 and per acre, Rs. 737.

In Karnal in 1963, the estimated cost for a sewerage scheme for a population of 68,000 was Rs. 446,668, and the cost per capita, Rs. 6.56. The ring sewer varied in section from 36" x 54" to 24" x 36". In yet another city, Hapur, the per capita cost in 1965 for a city sewerage system designed for a population of 40,000 was Rs. 32.12.

Even though the disposal was similar in all the three cases (disposal of sewage without treatment for irrigation), the variation in unit costs was wide. This is explained mainly by:

1. The design factors such as section population loads and area of service spread

2. The location of disposal point with reference to the core area served

3. The price difference in time and space

In view of the limited data on actual costs, cost data for estimating purposes should be developed on a case by case basis. However, for estimating on-site costs in Chapter V, data based on Tables 30 and 31 are used.

Construction costs for sewage disposal works reported in the field survey are plotted on Figure 10. Construction estimates for sewers and sewage treatment plants for the Calcutta Metropolitan District in 1966 are plotted in Figures 11 and 12. The disposal works and sewer costs are applied in the cost estimates of Chapter V.

Due to data constraints, no attempt is made to analyze AMO costs for sewerage systems. For purposes of Chapter V, AMO costs are estimated at 1/2 percent of construction costs, based on experience in the field region.

Table 30

UNIT COSTS FOR SEWERAGE FACILITIES
Industrial Areas - Delhi*

Industrial Estate	Area (acres)	Industrial Workers	Cost (Rs.) Total (000)	Per Worker	Per Acre
Okhla, Phase II	336.00	8,400	937.44	111.6	2,790
Anand Parbat	40.60	1,218	118.14	97.0	2,910
Azadpur	125.04	3,126	387.31	123.9	3,097
Weighted average				113.2	2,876

* These industrial estates were developed during 1963-65, and the cost data are from 1967 records.

Source: Delhi Development Authority, New Delhi.

Table 31

UNIT COSTS FOR ON-SITE SEWERAGE FACILITIES
Residential Areas
(Bareilly 1965=100)*

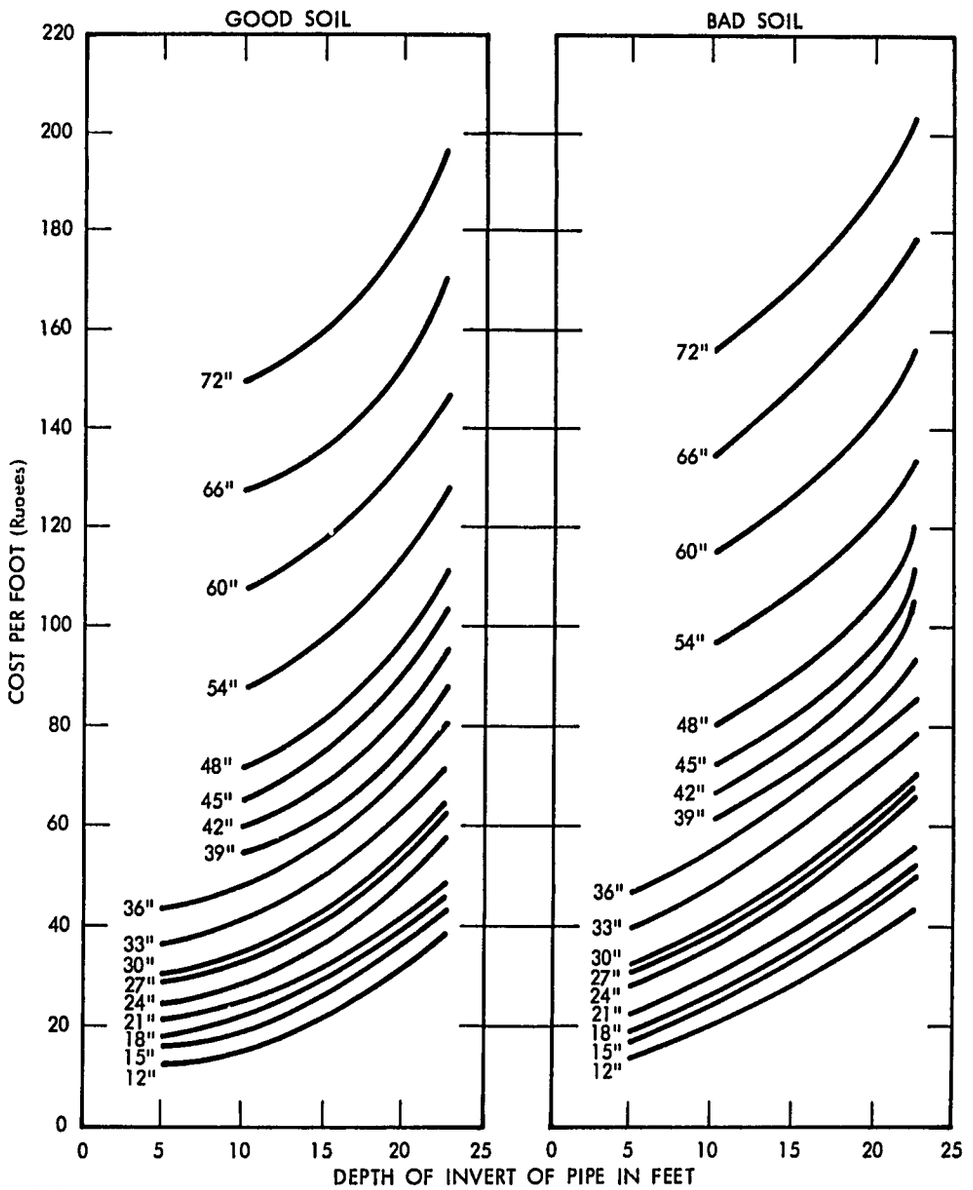
City	Year	Area (acres)	Unit Cost Rs./acre
Varanasi	1960	2.7	2,950
Varanasi	1964	2.8	3,030
Saharanpur	1964	4.4	3,730
Varanasi	1963	4.8	1,890
Varanasi	1964	6.1	1,600
Kanpur	1963	9.6	1,940
Kanpur	1963	11.6	2,320
Jullundur	1965	73.5	3,150

* Adjusted to Bareilly 1965 = 100 by road cost index.

Source: Field survey.

Figure 10

ESTIMATED CONSTRUCTION COST FOR REINFORCED CONCRETE PIPE, CALCUTTA



NOTE:

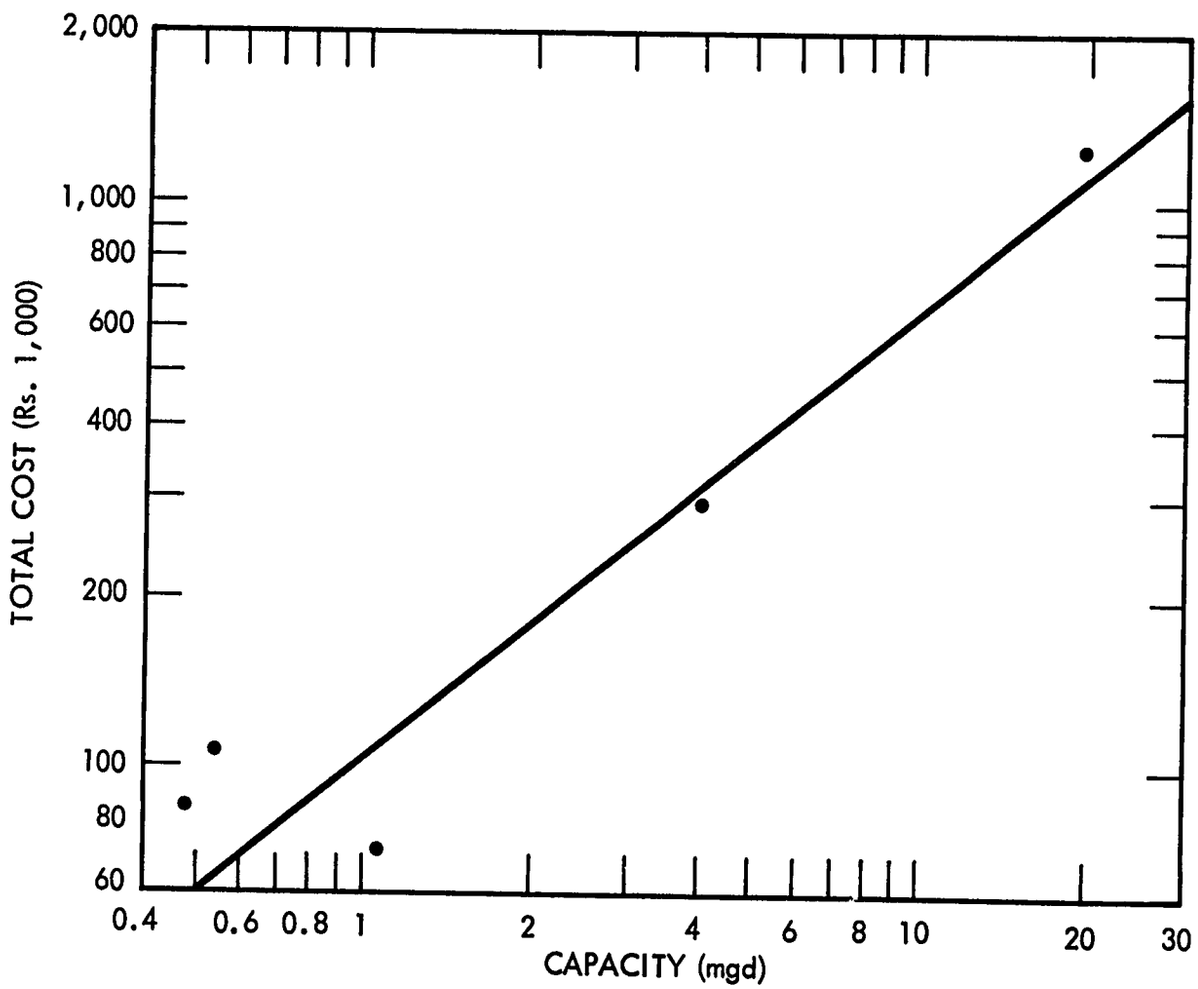
ADDITIONAL COST OF PAVEMENT	PIPE DIA. (Inches)	12-21"	24-36"	39-42"	45-48"	54"	60"	66"	72"
	COST PER FT. (Rupees)	4.00	5.60	6.00	6.40	6.80	7.20	7.60	8.00

NOTE: Unit costs shown above include cost of pipe, excavation, timbering and dewatering where necessary, laying and jointing, backfill, manholes (spaced at 250 ft) and contractors overhead and profit. Pavement replacement costs are scheduled separately and are additive.

SOURCE: Calcutta Metropolitan Planning Organization, Master Plan for Water Supply, Sewerage and Drainage, Calcutta Metropolitan District (1966-2001), report by engineering consortium, Metcalf & Eddy Ltd. and Engineering-Science Inc., December 1966.

Figure 11

ESTIMATED CONSTRUCTION COST OF SEWAGE DISPOSAL WORKS

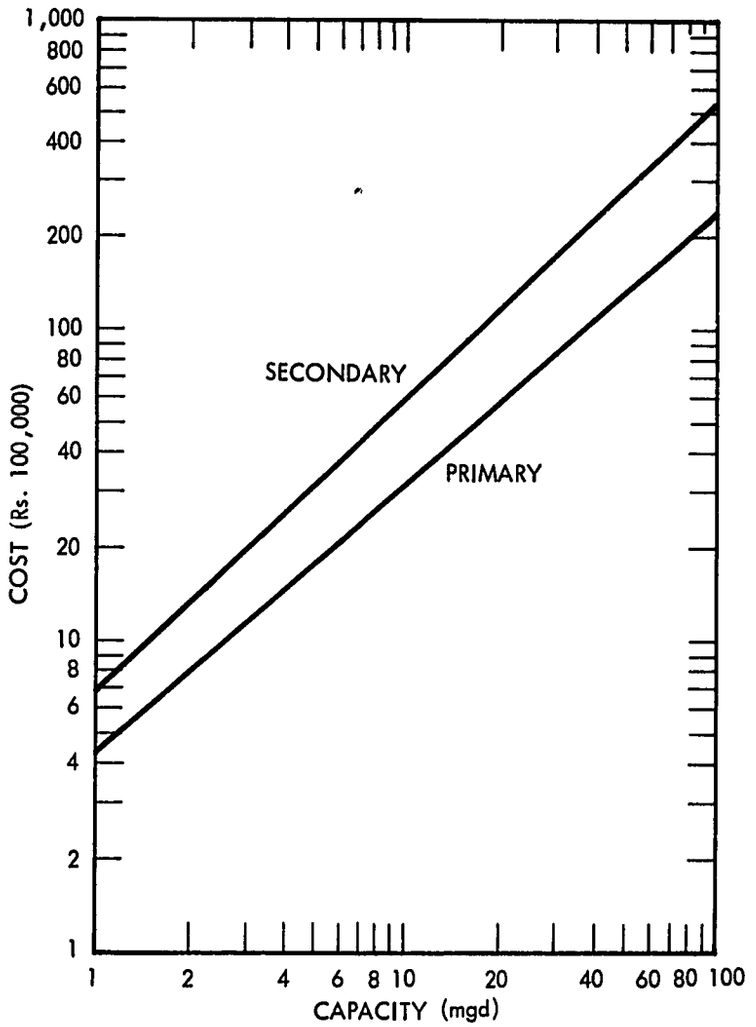


NOTE: Data includes screening chamber, pumping plant, rising main and collecting tank.

SOURCE: Field Survey.

Figure 12

ESTIMATED CONSTRUCTION COST FOR SEWAGE TREATMENT PLANTS, CALCUTTA



NOTE: Treatment plant costs provide for screening and grit removal, sedimentation, activated sludge or trickling filter type secondary treatment where applicable, sludge digestion, sludge drying bed, control facilities, and contractors overhead and profit. Costs for primary treatment are based on 30 percent BOD removal and costs for secondary treatment on 80 percent BOD removal. Costs of land, special foundations, and engineering and contingencies are not included.

SOURCE: Calcutta Metropolitan Planning Organization, Master Plan for Water Supply, Sewerage and Drainage, Calcutta Metropolitan District (1966-2001), report by engineering consortium, Metcalf & Eddy Ltd. and Engineering-Science Inc., December 1966.

Power

The principal power supply elements examined in this report are distribution systems serving urban areas. In order to put distribution costs in perspective, their share in total power system costs is first examined.

Share of Distribution in Total Power Costs. The magnitude of distribution costs as compared to generation, transmission, and other components of power cost is in part a conceptual and accounting question. In short term costs, it is difficult to assign to any single system element the burden of varying demand patterns, reflected in the utilization factor (ratio of peak load to system capacity), load factor (average load to peak load), and diversity or coincidence factor (time distribution of load). In long term costs, distribution's share usually depends more on regional conditions governing generation and transmission than on factors within the distribution system. Therefore, no simple share of total costs can be attributed to distribution for all systems and regions.

As an initial benchmark, distribution costs constituted approximately 20 percent of total operating expenses of the 212 companies that generated 75 percent of total power in the United States in 1966.* Relevant relationships are shown in Table 32.† Distribution facilities constituted nearly 40 percent of the value of the electric plant in use by these utilities. Distribution's share in the fixed plant was thus twice its share in total operating expenses. If interest charges on long term debt,

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* Taxes are excluded from this comparative analysis because of the wide variation in their incidence in different countries and cities. The utilities covered in Table 32 paid $3,031 million in taxes in 1966, or 21.8 percent of their total operating revenues.

† In establishing the cost breakdown of Table 32, depreciation and amortization charges were allotted in proportion to the value of plant used for production, transmission, distribution, and general purposes, as classified by the Federal Power Commission. This amounts to assuming equal life for each class of facility. This assumption is supported by the classes of useful life established as guidelines for tax depreciation allowances: distribution and transmission plant 30 years; steam production plant 28 years; hydraulic plant 50 years; nuclear plant 20 years. (U.S. Treasury Department, Internal Revenue Service, Depreciation Guidelines and Rules, Publication No. 456, Revised August 1964, p. 48). Since the steam plant forms over 84 percent of the value of the production plant in question, and is considered to have a useful life nearly equal to that of composite distribution facilities, pro rata allocation of depreciation and amortization charges is appropriate for the present purpose.

Table 32

COMPONENTS OF TOTAL OPERATING EXPENSES, EXCLUDING TAXES, OF PRIVATE ELECTRIC UTILITIES IN THE UNITED STATES, 1966

Category of Expense	Operation		Maintenance		Depreciation and Amortization*		Total Operating Expenses	
	Thousands of Dollars	Percent	Thousands of Dollars	Percent	Thousands of Dollars	Percent	Thousands of Dollars	Percent
Production	$3,429,279	62.5%	$354,013	38.1%	$ 650,981	40.4%	$4,434,273	55.3%
Transmission	108,642	2.0	85,418	9.2	273,927	17.0	467,987	5.8
Distribution	475,163 (30.2)	8.7	460,157 (29.2)	49.5	638,090 (40.6)	39.6	1,573,410 (100.0)	19.6
Customer accounts	376,243	6.8	--	--	--	--	376,243	4.7
Sales	263,288	4.8	--	--	--	--	263,288	3.3
Administrative and general	832,880	15.2	29,283	3.2	48,340	3.0	910,503	11.3
Total	$5,485,496	100.0%	$928,871	100.0%	$1,611,338	100.0%	$8,025,704	100.0%
Percent share of operating expenses	68.4%		11.5%		20.1%		100.0%	

* Allocated on pro rata basis as explained on page 122.

Source: U.S. Federal Power Commission, Statistics of Privately Owned Electric Utilities in the United States, 1966, FPC S-186, September 1967, pp. XV, XVI. Classification conforms to FPC, Uniform System of Accounts Prescribed for Public Utilities and Licensees, March 1, 1965.

amounting to $1,034 million, are allotted in proportion to the fixed plant, distribution's share in total costs rises to 25 percent.*

For urban systems, power distribution costs were examined for 23 Southeast Central U.S. cities, ranging from 10,000 to 500,000 population in 1960. Municipal utilities in these cities operated mainly with purchased power. Distribution costs varied from 21 to 28 percent of total operating expenses of 19 of these utilities in 1960, excluding interest and taxes but including depreciation and amortization as allocated above.† Distribution facilities accounted for 83 to 95 percent of the fixed plant operated by 18 of these municipal utilities.

A moderate threshold effect in distribution costs is evident in the above sample among the 19 municipal utilities which operated entirely with purchased power. Operating expenses for 14 utilities, all but one with annual sales over 100 million kilowatt-hours, were 6.83 to 7.26 mills per kilowatt-hour. No correlation between cost per unit and sales volume was observed for these 14 utilities Operating expenses in five utilities, however, all but one with annual sales less than 100 million kilowatt-hours, ranged from 7.64 to 8.55 mills per kilowatt-hour. Four of these five higher cost operations were in cities of the smallest size class, 10,000 to 20,000. The suggestion of an increase in unit distribution costs for annual sales of less than 100 million kilowatt-hours is apparent for these U.S. municipal utilities.

Components and Parameters of Power Distribution Costs. Capital charges are the largest component of distribution costs, nearly 41 percent of annual expenses, as summarized in Table 32. Operation accounted for 30 percent and maintenance 29 percent of distribution expenses. If interest on long term debt is allocated as above, capital represents almost 53 percent of the total distribution expenses of these utilities.

Major lineal and nodal components of distribution costs are identified as follows. In 1966, the utilities covered in Table 32 used distribution plant valued at $23,838 million.‡ Lineal facilities comprised by far the largest component, 55 or 81 percent, depending on classification. The lower figure includes poles, towers, and fixtures (16.6 percent),

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* Distribution's share in the total delivered costs of power on a national basis is understated by perhaps 3 to 4 percentage points in these figures, in that 15.3 percent of the kilowatt-hours produced by the reporting utilities was sold in bulk supply for resale, distribution costs being assumed mainly by resale agencies.

† Based on U.S. Federal Power Commission, Statistics of Electric Utilities in the United States, 1960, Classes A and B Publicly Owned Systems, FPC S-152, 1962, pp. 1-29.

‡ U.S. Federal Power Commission, Statistics of Privately Owned Electric Utilities in the United States, 1966, FPC S-186, September 1967, p. XXXIX.

overhead conductors and devices (16.3 percent), underground conductors and devices (6.2 percent), underground conduit (5.7 percent), street lighting and signal systems (4.0 percent), and consumer service lines (6.2 percent). Line transformers used in transforming electricity to consumer voltages (18.7 percent) and meters (7.1 percent) bring the value of lineal networks to 81 percent of total distribution plant.

Substations and related equipment constitute the principal nodal component, 17.3 percent of the total distribution plant of the reporting utilities in 1966. Land and land rights at 1.6 percent make up the balance.

The prominence of lineal elements in distribution costs is reinforced by the high share of power lines in maintenance and operation expenses. Overhead lines accounted in 1966 for 36.5 percent of combined operation and maintenance expenditures, underground lines accounted for 5.3 percent, and street lighting and signal systems accounted for 4.3 percent.* Substation M and O expenses were only 10 percent of the total. Other substantial elements were supervision and engineering, 11 percent; meters, 8 percent; and customer installations, 8 percent.

The above order of cost components suggests that the principal factors which influence distribution costs are, in order of influence:

1. Load characteristics, including required voltage level, resistance losses, and load factor. As related to distance, these features influence the design of distribution systems, including choice of materials and layout, and hence the level of costs.

2. Distance to consumers, reflecting the spatial density of consumer loads, city layout and street systems, and urban land use patterns.

3. Economies and diseconomies of scale in substations. The capacity of transformer stations is a function primarily of load characteristics and spatial distribution. Cost variation follows from scale effects in substation facilities.

   The parameter of distance, as influencing requirements for lineal facilities in cities of different size, is considered in Chapter V. Load characteristics are reflected in the estimates on incremental

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* Ibid., p. XXXXV. In interpreting the relative weight of lineal, nodal, and other cost components, the qualification must be noted that both urban and rural distribution systems are combined in the above figures. Comparable rural and urban breakdowns are not available, nor is the number of rural consumers separately identified after 1960 (FPC S-186, p. XXIX). However, only 4.5 percent of the consumers served in 1960 by the reporting utilities were rural. Rural requirements for lineal facilities, therefore, cannot significantly account for the weight of lineal components shown above.

power costs reported in that chapter. Groundwork for that discussion is laid below in a summary of scale economies and diseconomies in power distribution facilities.

Scale Factors. Since lineal facilities are predominant in distribution costs, it is reasonable first to consider what effect system length may have on unit costs. Available evidence indicates that for given current-carrying capacity and construction conditions, construction costs per mile are virtually constant.* Resistance losses, which may be expressed as kw/mile are in direct proportion to length of line. Distribution elements in both capacity and energy costs may therefore be taken as a linear function of the length of distribution lines. Original and annual costs per mile are shown in Table 33 for U.S. transmission lines of voltages common to feeder lines in urban distribution systems.

Scale effects occur primarily in substations. Table 34 shows total and unit construction costs of outdoor type substations in three voltage ranges, each of varying kva capacity Economies of scale are significant in each range. Costs per kva drop sharply for lower capacity substations of each type, and more gradually for higher kva capacities, until the largest sizes are reached. Diseconomies of scale are evidenced in a rise in unit costs for the largest installations in the 13,800/4,160 voltage category (at 7,500 kva capacity) and the 345,000/13,800 category (at 300,000 kva capacity).

Substation costs for the highest voltage category in Table 34 do not represent "pure" scale effects, as the specified input voltage changes with station capacity. These voltages may be taken as representative for the respective capacity levels. Holding input voltages constant over applicable capacity levels would slightly reduce transformer costs, but would not appreciably alter the relative positions of unit costs. Details on major elements of substation cost, Table 35, indicate that a significant increase in switchgear requirements from stations of 200,000 kva to 300,000 kva capacity is the main component in higher unit costs for the larger station.

Effects of scale on the costs of operating and maintaining power substations are shown in Table 36 in dollars per kva and as an index to least unit cost. Operation and maintenance costs per kva fall more sharply than capital costs, and continue to decline over the whole capacity range up to 300,000 kva. Annual capital costs and total annual costs are also shown in Table 36. Operation and maintenance costs drop from 42 percent of total annual costs for 5,000 kva substations to 31 percent for 300,000 kva stations.

The combined scale effect of capital and current substation costs, seen in the "Total" columns of Table 36, is a decrease of about 50 percent

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* Reference 76, pp. 23-88.

Table 33

TRANSMISSION LINE COSTS PER MILE--UNITED STATES
1962

Type	Line Voltage (kv)	Total Construction Cost* ($)	Annual Costs: Capital† ($)	Annual Costs: Interim‡ Replacements ($)	Annual Costs: Operation and Maintenance ($)	Annual Costs: Total ($)
Single wood pole single circuit	33	$ 6,200	$ 379	$12	$130	$ 521
Single wood pole single circuit	66	8,300	507	17	185	709
Steel tower single circuit	66	24,730	1,355	25	130	1,510
Steel tower single circuit	132	34,900	1,942	35	185	2,162

* Includes poles, towers and fixtures, conductors, insulators, groundwire and hardware, and 15 percent general overheads. Excludes right-of-way and clearing costs.

† Based on service life of 35 years for lines on wood poles, and 50 years on steel towers. Interest @ 5 percent. Capital recovery factor .06107.

‡ At 0.20 percent of investment for wood pole lines and 0.10 percent of investment for steel tower lines.

Source: Based on U.S. Federal Power Commission, Instructions for Estimating Electric Power Costs and Values, Technical Memorandum No. 1, March 1960, and Supplement No. 1, Change in Price Levels, Jan. 1, 1960 to Jan. 1, 1962, July 1962, p. 28.

Table 34

CONSTRUCTION COSTS OF ELECTRICAL SUBSTATIONS, OUTDOOR TYPE, EXCLUDING LAND--UNITED STATES

Date	Transformer Voltage (volts)	Capacity (kva)	Total Cost ($)	Unit Cost ($/kva)	Index to Least Unit Cost (%)
July 1959[a]	4,160/600	112	$ 9,970	$89	247%
		150	10,650	71	197
		200	11,200	56	156
		225	12,150	54	150
		300	13,500	45	125
		500 and over	18,000	36	100
July 1959[a]	13,800/4,160	300	21,000	70	269
		500	31,000	62	239
		600	35,000	59	227
		1,000*	42,000	42	162
		1,500†	45,000	30	115
		1,500*	48,000	32	123
		2,000†	68,000	34	131
		2,000*	76,000	38	146
		3,750‡	97,500	26	100
		7,500§	217,500	29	112
January 1962[b]	34,500/13,800	5,000	173,960	35	500
	46,000/13,800	10,000	252,500	25	357
	69,000/13,800	20,000	342,910	17	243
	115,000/13,800	50,000	666,430	13	186
	138,000/13,800	75,000	843,050	11	157
	161,000/13,800	100,000	1,047,220	10	143
	230,000/13,800	200,000	1,488,010	7	100
	345,000/13,800	300,000	2,827,480	9	129

* 3 taps.
† 2 taps.
‡ 4 taps.
§ 6 taps.

Sources: Based on:

a. U.S. Dept. of Navy, Design Manual: Cost Data for Military Construction, 1961, pp. 454-455.

b. U.S. Federal Power Commission, Instructions for Estimating Electric Power Costs and Values, Technical Memorandum No. 1, revised March 1960, p. 77, and Supplement No. 1, Change in Price Levels Jan. 1, 1960 to Jan. 1, 1962, July 1962, p. 18.

Table 35

PRINCIPAL ELEMENTS IN CONSTRUCTION COSTS OF
ELECTRICAL SUBSTATIONS, OUTDOOR TYPE, EXCLUDING LAND
., January 1962

Transformer Voltage (kv)	Capacity (kva)	Structures and Improvements ($)	Conduits, Wiring, Busses, etc. ($)	Switchgear ($)	Transformers ($)	Total Cost ($)
34.5/13.8	5,000	29,760	29,780	65,140	22,540	173,960
46.0/13.8	10,000	42,130	44,180	88,530	38,770	252,500
69.0/13.8	20,000	56,110	68,940	106,020	57,240	342,910
115.0/13.8	50,000	91,070	102,950	203,820	128,000	666,430
138.0/13.8	75,000	124,680	138,120	224,860	180,000	843,050
161.0/13.8	100,000	160,510	173,450	284,240	225,400	1,047,220
230.0/13.8	200,000	236,090	213,800	415,400	376,500	1,488,010
245.0/13.8	300,000	306,100	329,200	1,260,000	586,500	2,827,480

Notes: All costs include allowances for materials, equipment, labor, and construction overhead (15%). The costs of substation structures and improvements provide for the main supporting structure, clearing, grading, drainage, landscaping, fencing, roads, walks and the yard lighting system. These costs are representative of substations constructed on fairly level sites and, therefore, should be modified for substations on side-hill sites or on two or more levels, involving added excavation, retaining walls, etc. The costs of conduits, wiring, busses, etc. include conduits, duct lines, pipe, envelopes, manholes and covers, power and control wiring, plugs and receptacles, busses, cable, tubes and fittings, together with insulator supports and hardware. The total cost of these items has been allocated approximately as follows: 25 percent to transformer positions, 55 percent to oil circuit breaker positions, and 20 percent to air switch positions. The cost of switchgear covers oil circuit breakers, manually-operated, three-pole, single-throw disconnect switches, and motor-operated air break switches. Main power transformer cost is applicable to three-phase installations, i.e., one three-phase transformer. Total costs also include costs for protective equipment, auxiliary equipment, and carrier current equipment, not shown separately.

Source: U.S. Federal Power Commission, Instructions for Estimating Electric Power Costs and Values, Supplement No. 1, Change in Price Levels Jan. 1, 1960 to Jan. 1, 1962, July 1962, p. 18.

Table 36

ECONOMIES OF SCALE IN ELECTRICAL SUBSTATIONS*--UNITED STATES
1962

Substation Capacity (kva)	Annual Cost Per KVA				Index to Least Unit Cost		
	Capital† ($)	Interim‡ Replacements ($)	Operation and Maintenance ($)	Total ($)	Capital (%)	Operation and Maintenance (%)	Total (%)
5,000	$2.14	$.12	$1.62	$3.88	498%	623%	485%
10,000	1.53	.09	1.13	2.75	356	435	344
20,000	1.04	.06	0.81	1.91	242	312	239
40,000§	0.85	.05	0.65	1.55	198	250	194
50,000	0.79	.05	0.56	1.40	184	215	175
100,000	0.61	.04	0.43	1.08	142	165	135
200,000	0.43	.02	0.35	0.80	100	135	100
300,000	0.55	.03	0.26	0.84	128	100	105

* Receiving substation, 13,800 volt output.
† Based on service life of 35 years, interest @ 5 percent. Capital recovery factor .06107.
‡ Estimated at .35 percent of original investment.
§ Estimated.

Source: Based on U.S. Federal Power Commission, Instructions for Estimating Electric Power Costs and Values, Technical Memorandum No. 1, March 1960, and Supplement No. 1, Change in Price Levels, Jan. 1, 1960 to Jan. 1, 1962, July 1962, p. 28.

in annual unit costs for stations in the 5,000-20,000 kva range, a decrease of about 25 percent in the 20,000-50,000 kva range, and a decrease of 30 to 35 percent in the 50,000-200,000 kva capacity range. Annual unit costs then rise by 5 percent at a capacity of 300,000 kva.

Power distribution facilities are of course designed to capacities considered appropriate in light of demand or load surveys for a given area, with scale effects entering as a secondary consideration. In the context of the present study, the order of magnitude of net scale effects in urban distribution costs is of interest. Our earlier partition of costs is relevant for this purpose. We have seen that the costs of lineal facilities, which on the average account for about 80 percent of total distribution costs, are a constant function of distance.* Scale effects are operative primarily on the 20 percent of costs represented by nodal facilities. For illustrative purposes, focussing on city receiving stations and ignoring neighborhood transformers of lower capacity, we will assume that the 20 percent cost share is achieved by systems which on the average use 100,000 kva substations. A system utilizing a 50,000 kva substation would then experience 6 percent higher annual costs of distribution attributable to scale effects (the 20 percent cost proportion times the 30 percent higher unit substation costs seen in Table 36). A system using a 10,000 kva station would experience 31 percent higher distribution costs than one with a 100,000 kva station (20 percent times 155 percent). These illustrations are extreme, because they are not related to the tiered system of receiving and distribution substations actually used. They may serve to place scale effects in a meaningful perspective, recalling that distribution costs per se constitute approximately 25 percent of total delivered costs of power.

Costs of Power Distribution in India. The types and sizes of distribution system elements installed in recent years in the 18 surveyed cities differ widely, precluding effective comparative analysis of construction costs. The following cost information on substations and distribution lines is based on details provided in the consulting engineering report on power facility costs for new industrial and residential areas in five developmental cities.

Cost components for two types of transformer substation are itemized in Table 37. Distribution stations to reduce 11 kv subtransmission line voltage to the 415 volts distributed to industrial and domestic users are included at two capacities. Installed costs per kva fall from Rs. 480 in a 300 kva station to Rs. 296 in a 1,000 kva station. This closely parallels the decrease in unit costs in U.S. substations of the same capacity, in the intermediate voltage range shown in Table 34.

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* For analysis of the effects of voltage requirements and load distribution on line costs, which is beyond the scope of this study, see reference 76, p. 23-88.

Table 37

ESTIMATED CONSTRUCTION COSTS OF ELECTRICAL SUBSTATIONS--INDIA
1967

Item	Costs by Substation Type and Capacity			
	11 kv/415 Volts Distribution Station		33/11 kv Receiving Station	132/11 kv Receiving Station
	300 kva (Rs.)	1,000 kva (Rs.)	15,000 kva (Rs.)	40,000 kva (Rs.)
Isolators and fuse links	300	800	7,000	30,000
Oil circuit breaker	0	0	60,000	200,000
Transformers	15,000	44,000	400,000	1,100,000
Switchgear	90,000	170,000	180,000	410,000
Conductors, insulators, metering and miscellaneous	2,700	5,200	65,000	150,000
Building	12,000	27,000	45,000	72,000
Subtotal	120,000	247,000	757,000	1,962,000
Erection @ 20 percent	24,000	49,400	151,400	392,400
Total Substation Cost	144,000	296,400	908,400	2,354,400
Cost per kva	480	296	61	59
Annual cost equivalent*				
5 percent interest	9,684	19,781	57,254	147,835
10 percent interest	15,515	31,837	95,366	246,804

* Useful life assumed as 25 years for switchgear, 35 years for transformers and installations. See United Nations, Economic Commission for Asia and the Far East, Public Electricity Supply-A Manual on Management, New York, 1965, p. 8.

Source: The Kuljian Corporation (India) Private Ltd., Consulting Engineers, New Delhi.

The receiving substations shown on Table 37 evidence only a negligible decrease in unit costs. Cost per kva for a 33/11 kv station of 15,000 kva capacity is Rs. 61, compared to Rs. 59 per kva for a 132/11 kv station of 40,000 kva capacity. The largest component of costs in these substations are the main power transformers, two each of 7,500 kva and 20,000 kva respectively. These exhibit no reduction in unit cost, being estimated at Rs. 26.66 and Rs. 27.50 per kva respectively. By contrast, the cost of transformers in the U.S. stations reported in Table 35 decreases from $3.88 per kva in a 10,000 kva installation to $2.56 per kva in a 50,000 kva substation. Quotation for the larger equipment in India at a price that does not reflect normal size differentials may represent a temporary market position, so that the apparent absence of scale economies in receiving substation costs must be taken with qualification.

Costs of four types and voltages of distribution and subtransmission lines are detailed in Table 38. Specifications of these lines are not directly comparable to U.S. lines shown in Table 38, except for the 132 kv single circuit line on steel towers, for which actual U.S. cost is substantially higher at official exchange rates. Use of heavier towers (10,000 pounds as against 6,300 pounds) at higher cost in-place explains a substantial part of the difference.

Information on street lighting, on-site distribution, and city power system AMO costs developed by the consulting engineers for estimation of incremental power costs is summarized in Chapter V.

Telephones

Review of India Field Data. Telephone facilities in the 18 cities are provided by a centralized agency, the Post & Telegraph (P & T) Department of the central government. The state and local government authorities, by and large, have little to do with the provision of this facility. More than 80 percent of the cities studied had manually operated telephone exchanges and the rest had automatic dialing exchanges.* There appeared to be no effective standards for the number of telephones for various population ranges. In a majority of cases, the number of telephones available in the city depended on equipment availability rather than on the demand for telephones.†

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* See City Inventory, p.251. Automatic dialing systems were present only in Kanpur, Jullundur, and Varanasi.

† In India during the period of study, telephone exchange equipment and telephones were under manufacture by a single public sector firm. Since the demands far exceeded the available equipment and instruments, allocations were on a priority basis. Various public agencies and metropolitan areas commanded comparatively higher priorities. Utilization of equipment reflects this situation. Generally the exchanges are overstressed and some of the equipment is in reuse. The spare "boards" resulting from conversion of manual to automatic exchanges are utilized to provide for new connections in waiting areas.

Table 38

TRANSMISSION AND DISTRIBUTION LINE COSTS--INDIA
1967

Line Voltage and Description	Rating (kva)	Cost* Per Mile (Rs.)
11 kv single circuit, rail poles		
.02 sq in. A.A.C. conductor	1,200	8,474
.10 sq in. A.A.C. conductor	6,000	23,376
11 kv double circuit, rail poles		
.10 sq in. A.A.C. conductor	7,000	41,479
33 kv double circuit, rail poles		
.05 sq in. A.A.C. conductor	20,000	31,586
132 kv single circuit, steel towers		
.075 sq in. A.C.S.R. conductor	40,000	78,296

* Cost includes phase and ground conductors, towers and poles, insulators, brackets, foundations, and erection charge @ 20 percent of material costs.

Source: The Kuljian Corporation (India) Private Ltd., Consulting Engineers, New Delhi.

The expenditures of the P & T Department appear to be more related to the facility scale function (number of telephone connections) than to population size. The variables are too many and data too few for any meaningful analysis of expenditures by city size. Data on capital costs were practically nil because of the form of accounting by a centralized agency and financial allocations on a year-to-year basis for capital expenditures. During the period under review, there was practically no new construction of buildings for telephone exchanges and the majority of them were located either in old buildings or in leased premises.

Annual expenditures by the telephone department in selected cities are presented in Table 39. Per capita expenditures range from the low Rs. 0.2 to the high Rs. 1.99. More than 75 percent of the expenditure is accounted for by salaries and wages, with the exception of Karnal. Per capita expenditure appears to increase with an increase in number of telephone connections in cities, although there is no significant correlation.

It is sufficient to say that per capita expenditures are meaningful only when variables of capital inputs and service outputs are measured in detail. For estimating costs in the five test cities in Chapter V, the average cost per telephone connection, Rs. 225, is used.

Housing

The principal type of housing examined in this section is housing for industrial workers - "Industrial Housing." Housing costs are by definition divided into several components: (1) building costs, (2) site development costs also known as "service costs," (3) maintenance and operation costs, and (4) land costs. Excluding land costs,* it is useful to clarify the three main components.

1. Building costs include the building with internal electric, water supply, and sanitary installations.

2. Site development or service costs include the cost of physical development of site with levelling/grading, roads and drainage ways, water supply mains, sewer mains, open spaces including parks, street lighting, and landscaping.

3. Maintenance and operation costs include the upkeep of the site and buildings to ensure that housing conditions remain at an acceptable standard over a certain period.

It is important to place the evaluation of housing cost within the wider context of physical planning, which provides the framework of rational location of residential space, communications, recreational centers,

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* Within the context of this report, the term "housing cost" excludes land costs.

Table 39

TELEPHONE DEPARTMENT EXPENDITURES
1966-67

City*	Population (000)	No. of Telephone Connections	Annual Expenditures (Rs.) Total Amount (000)	Total Per Capita	Salaries and Wages Amount (000)	Salaries and Wages Per Capita	Salaries and Wages % of Total	Expenditures per Single Connection
Kanpur	1,070	9,344	2,134	1.99	2,056	1.92	96%	228
Varanasi	573	3,698	n.a.	n.a.	201	0.35	n.a.	n.a.
Gorakhpur	216	982	373	1.73	360	1.66	97	379
Saharanpur	212	879	324	1.53	264	1.25	81	369
Patiala	145	980	39	0.27	30	0.21	77	40
Ambala City	90	631	107	1.19	95	1.05	89	170
Karnal	81	360	17	0.21	8	0.09	48	47
Jagadhri†	66	320	75	1.14	72	1.09	96	235
Phagwara	48	271	28	0.58	27	0.56	96	103

n.a. = not available.
* Data for other cities not available.
† Jagadhri city only.

Source: Field reports from local offices of Post & Telegraph Department.

and other facilities. As will be seen in Chapter V, space requirements for schools, health facilities, parks, and other community services must be taken into account together with housing in providing for urban residential areas. It should be stated, at the outset, that precise cost figures for housing elements are not possible. The housing situation is a dynamic one, and housing requirements are influenced by a number of changing factors. Levels of accuracy and detail in which housing costs are expressed will depend upon the purpose for which these are to be used and also the conditions under which they are estimated.

Influence of Principal Variables on Unit Costs. Densities in urban residential development have a direct effect on the structural standards of housing and therefore on cost. High density multistory development requires higher structural standards and more expensive materials than lower density housing. Stone* has shown that the total cost per dwelling increases when density is increased beyond a certain range, even though the cost of land development and public facilities per dwelling decreases (Figure 13).

Structural costs are also influenced by the foundation soil conditions and by earthquake potential. Variation in standards of accommodation (floor space per dwelling, balconies, verandas, lavatories, and other equipment) greatly influences the cost of construction per dwelling. The standard of accommodation is related to present economic, social, and educational levels of the people and also to the rate of population and employment growth. When standards of accommodation have been fixed, there will still be many alternative architectural designs which meet the requirements of the standard. These alternatives differ in cost, and actual construction cost will therefore depend heavily on the architectural design and efficiency.

Equally important is the engineers' and contractor's efficiency in structural design, choice of materials, and technique of construction. Experience† has shown that considerable reduction in building costs can be achieved by attention to building materials, labor, and builder's equipment. Proper selection of specifications has considerable bearing on the finished cost of a building because the prices of different materials going into the building vary from place to place. Therefore, with given prices of materials and labor, certain specifications will produce cheaper housing than others, even though the standards and the expected life of the structures may be the same.

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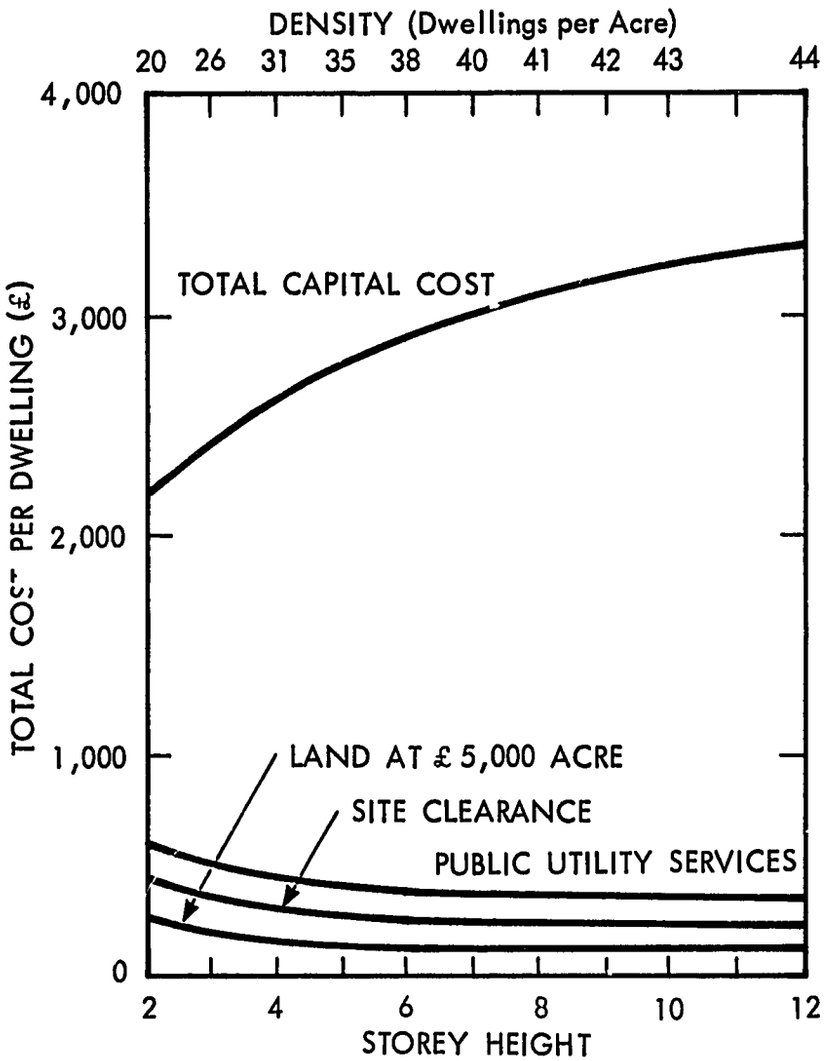
* Reference 86, pp. 41 and 118.

† United Nations, Economic Commission for Asia and the Far East, Study on Building Costs in Asia and the Far East, Sales No. 61.II.F.9., Bangkok, 1961, p. 13. See also reference 92.

Figure 13

DWELLING COSTS RELATED TO BUILDING DENSITY, GREAT BRITAIN



NOTE: Capital costs are of three-bedroomed dwellings in flatted blocks in central areas in the provinces according to type of cost.

SOURCE: Stone, P. A., Housing, Town Development, Land and Costs, The Estates Gazette, Ltd., London, 1963, P. 118.

Analysis of India Field Data. Most of the field data collected was for public housing. This includes industrial housing as well as government rental housing for government employees. The buildings are for the most part of brick masonry with flat reinforced cement concrete (RCC) roofs, either in terrace housing (rows) blocks, or detached units. Most of the industrial housing is in two story buildings each containing six to eight dwelling units, except in Kanpur where the buildings are four stories and each contains 25-30 dwellings.

The minimum standard dwelling unit for low income groups is one room with adjoining kitchen, bath, and latrine. The plinth area* of the minimum size unit varies from 304 to 384 square feet. The more typical low income housing is the two-room dwelling unit, which ranges in plinth area from 338 to 621 square feet and is two rooms with kitchen, bath, latrine, and a veranda. The structure is mainly brick masonry on cement concrete foundations, with partition walls of 9 inches, load bearing walls and stair case walls 13-1/2 inches thick, and RCC flat roof. In some of the earlier constructions, reinforced brick roofs instead of RCC roofs were used.

Compared with the above, the government rental housing varies in specifications, standards, and type of dwelling from the minimum 240 square feet to 1,592 square feet. This is mostly on a sliding scale, depending on the income level. In the upper ranges, the buildings are mostly single story, either detached or semidetached, with two or three bedrooms.

The plinth area unit cost per square foot varies from a low of about Rs. 9 in single and double story industrial housing to a high of nearly Rs. 28 in government rental housing. This wide variation is due to differences in standards and specifications between industrial housing and rental housing, the latter having higher standards of space, electrical and sanitary fittings, floor finishing, woodwork, and other elements.

Generally, housing projects--especially industrial housing--are executed by the public works department (PWD) through contractors, by percentage rate contract.† It usually takes more than a year to complete a housing project. Preliminary work, such as acquisition and development of land, preparation of designs and estimates, and invitations to tenders, is done by the PWD. This cost is borne in the total project cost and varies from 4 to 8.5 percent, depending upon the size and duration of the project.

The budgetary system and the amount of subsidy the government provides for housing, especially industrial housing, has a good deal of impact on the number and type of units constructed and thereby on the total stock of housing availability. This government policy impinges on the overall efficiency of the building industry and is reflected in variations

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* Foundation or base course area.

† See p. 59.

in unit costs of building materials, construction labor, and complete dwellings. However, since the variables and external factors are many, from funding to administration and execution, it is difficult to quantify them.

The timing of public expenditure for housing has another important and far reaching effect on unit cost. Generally, the expenditure is sanctioned by the government for the entire project, but actual allocation is on a yearly basis. This in reality has a "reverse effect" on the unit cost, depending upon the funds released in any one fiscal year. A large allocation, in conventional terms, would be expected to have the effect of lowering unit costs. But the yearly fluctuations in the budgetary provisions have an adverse effect and generally tend to increase the unit cost, aside from their impact on other elements in the economy as a whole. Generally, the total project gets completed over a period of years, during which the site development, construction of buildings and provision of amenities occur arbitrarily, so that the economies of scale or organizational efficiency are lost in the total process.*

This is a principal reason why the field data are not sufficient for effective studies of economies of scale in either unit costs of building construction or site development.

In order to correct reported costs for purposes of analysis, the building cost index previously described† was developed. A typical low cost housing unit of 500 square feet plinth area was selected as the basis of the index. In brief, its specifications are: foundations on a concrete base, brick masonry load bearing walls for superstructure, timber doors and windows, RCC flat roof. We calculated the quantity of each structural item, such as foundation concrete, brick work, doors and windows, and then further differentiated these amounts into nine basic items of material and labor. Multiplying these requirements by material and labor prices (Appendix A) provided the total building costs that were used as the basis of the cost index (Table 40). For the average prices in 18 cities in 1965, the percentage of cost for each basic requirement was:

Bricks	18%
Cement	18
Sand	5
Stone aggregate	7
Mild steel	12
Timber	11
Mason	11
Carpenter	8
Unskilled labor	10
Total	100%

* See United Nations, ECAFE, op. cit., p. 8, for a discussion of governmental policies and organizations for contract construction cost reduction.

† Pages 60 to 62.

Table 40

BUILDING COST INDEX FOR INDUSTRIAL HOUSING
18 Cities, 1962-67
(Base - Bareilly 1965 = 100)

State and City	1962	1963	1964	1965	1966	1967
Punjab						
Jullundur	97	98	99	99	110	124
Phagwara	92	95	98	108	120	131
Ludhiana	93	97	101	107	119	130
Patiala	88	90	92	97	107	115
Haryana						
Ambala	92	94	97	103	114	124
Jagadhri-Yamunanagar	88	91	95	100	109	117
Karnal	89	91	94	101	109	124
Bhiwani	88	91	95	100	110	117
Uttar Pradesh						
Saharanpur	77	80	83	90	93	101
Modinagar	82	85	89	96	102	112
Hapur	94	98	101	110	117	130
Amroha	80	85	89	95	103	113
Bareilly	87	90	94	100	105	116
Kanpur	86	90	93	98	103	117
Faizabad	77	81	84	91	100	112
Gorakhpur	84	89	92	101	108	119
Maunath Bhanjan	89	94	97	106	110	126
Varanasi	82	86	89	97	103	111

In a permanent structure of this type, even though timber accounts for a substantial share of cost, an appreciable percentage of money is spent on bricks, cement, and steel. Nearly 29 percent of the total cost is accounted for by labor, the remaining 71 percent being materials. The construction technique is more oriented to manual labor than to any sophisticated construction equipment. Even though concrete mixers, vibrators, and hoists are becoming common in large projects, especially for multistory buildings, it appears that because of the lower level of wages for unskilled workers in the building industry, expensive machines are not in use.*

Adjusted costs per square foot for buildings of different plinth area are presented in Table 41 for industrial housing and Table 42 for government rental housing. The reported industrial housing projects include one, two, and four story units, the number in each category being too few to permit significant analysis. Perhaps the most meaningful comparison that can be made is the following summary of average cost per square foot for each type of housing.

	Rs./sq ft
Industrial housing	
One story	11.26
Two story	11.43
Four story	13.33
Government rental housing	
(Mostly one story)	14.02

Inspection of the adjusted field data on industrial housing (Table 41) indicates that in single story construction, the unit cost tends to decrease slightly with increases in plinth area. In two story construction, the unit cost increases slightly. In both instances, the tendency is barely perceptible, and the number of erratic points is too many, in such a small sample, to permit meaningful inferences. It appears that there is a common point around 460-500 square feet, where the unit cost is about the same for both one and two story construction.

For government rental housing, unit costs vary considerably about a mean of Rs. 11.55 for 14 projects up to 931 square feet of plinth area, but are substantially higher for five projects of 948 to 1,592 square feet. This is apparently due to the different specifications, as well as standards of internal fixtures. used in the low income group quarters, compared with the high income officers quarters. In the lower unit cost ranges, below 500 square feet, the construction is predominantly two story, whereas in the higher ranges, it is one story, either detached or semidetached. Despite these variations, a simple regression over the whole range from 240 to 1,592 square feet indicates a significant correlation at the

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* See United Nations, ECAFE, op. cit., p. 22.

Table 41

AREA AND UNIT COSTS OF
INDUSTRIAL HOUSING, INDIAN CITIES
(Bareilly 1965 = 100)

City	Year	Plinth Area (sq ft)	Unit Cost (Rs./sq ft)
One story			
Varanasi	1961	304	12.29
Ludhiana	1960	330	9.62
Phagwara	1957	337	12.19
Varanasi	1961	384	10.65
Varanasi	1961	463	11.77
Varanasi	1961	522	11.03
Two story			
Modinagar	1966	335	15.43
Kanpur	1963	338	9.67
Kanpur	1963	356	9.48
Kanpur	1962	460	12.05
Modinagar	1966	462	12.30
Kanpur	1963	476	10.22
Modinagar	1966	540	8.76
Modinagar	1966	621	13.51
Four story			
Kanpur	1963	338	12.92
Kanpur	1963	356	13.73

Source: Field surveys.

Table 42

AREA AND UNIT COSTS OF
GOVERNMENT RENTAL HOUSING, INDIAN CITIES
(Bareilly 1965 = 100)

City	Year	Plinth Area (sq ft)	Unit Cost (Rs./sq ft)
Maunath Bhanjan	1967	240	10.12
Kanpur	1966	360	11.86
Kanpur	1966	374	14.90
Kanpur	1966	479	13.99
Jullundur	1961	517	10.56
Kanpur	1966	555	14.68
Maunath Bhanjan	1967	754	8.33
Karnal	1966	760	10.71
Jullundur	1961	798	10.27
Jullundur	1966	828	10.80
Kanpur	1966	854	13.64
Maunath Bhanjan	1967	896	8.82
Karnal	1966	910	10.71
Jullundur	1966	931	11.77
Modinagar	1966	948	19.62
Modinagar	1966	981	26.19
Modinagar	1966	1,504	27.67
Varanasi	1962	1,500	14.85
Varanasi	1962	1,592	16.85

Source: Field surveys.

95 percent significance level* for unit costs, increasing gradually as a linear function of plinth area. This would be consistent with gradually higher standards and hence costs for government workers receiving higher pay.

Data on annual maintenance and operation costs for specific housing projects are not separately identifiable in departmental accounts. For purposes of Chapter V, AMO costs are estimated at 1-1/2 percent of construction costs, the standard figure used in the survey region.

Site Development. Site development cost data pertain mostly to public housing projects and, inevitably, are spread over a number of years. Generally, site development such as filling and leveling, constructing roads, and laying water and sewer lines is done departmentally by the two wings of the PWD, namely the Building and Roads section and Public Health section.†

The costs of site development obtained in field studies were adjusted to Bareilly 1965 prices on the basis of the index of road costs.‡ The fragmentary way in which sites are developed makes it difficult to obtain comprehensive data applicable to comparable types. It was found that costs of site development, including street lighting, varied from Rs. 9,300/acre to Rs. 23,800/acre (Table 43). These figures do not, in the available form, give any information as to the effect of density, type of development terrain, or soil type on the cost of each developed acre. The area range from 2.7 to 11.6 acres is too small to arrive at any broad conclusions. From overall considerations, the Improvement Trust acreage of 73.5 at Rs. 16,100/acre is most typical for site development cost. Approximately 30-38 percent of the total cost of the reported projects goes for roads, 20-30 percent for sewers, 20-29 percent for water supply, and 1-4 percent for street lighting. In the case cited for Improvement Trust, the percentage components are: 13 percent for levelling, 31 percent for roads, 20 percent for sewerage, 29 percent for water supply, 1 percent each for street lighting and landscaping, and 5 percent for other cost items, including overhead and maintenance during development.

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* $R = .49$, $R_{.99} = .503$. For a two-sided test, significant at 97 percent.

† In Uttar Pradesh, water supply and sewers are developed mostly by Local Self Government Engineering Department or Engineering Wing of the State Housing Board.

‡ The road index was used because of the large road component in site development and because site preparation closely resembles road construction in labor inputs.

Table 43

COST OF SITE DEVELOPMENT
(Bareilly 1965 = 100)

Developed Area (acres)	Unit Cost (Rs./acre)
2.7	14,600
2.8	23,000
4.4	23,800
4.8	11,500
6.1	9,300
9.6	16,100
10.4	17,600
11.0	13,300
11.6	22,500
73.5	16,100*

* Developed by Improvement Trust.

Source: Field survey.

Schools

Educational costs as analyzed in this report are limited to those of primary and secondary schools. Technical and vocational schools as well as engineering and other technological institutions, which are of critical importance to industrial development, serve a regional as well as a local function. To the degree city size is a factor in the location of specialized educational institutions, this reflects the city's service functions for the region as a whole, in addition to local industrial requirements. It appears desirable to focus the present study on the costs of social infrastructure directly required for industrial increments in different size cities, rather than attempting an allocation of costs for institutions which serve a major regional function as well.

General Cost Considerations. New construction costs for educational facilities vary within the same local and geographic area and region. The quality of construction materials, the size of the building, and the ability of the cognizant society to pay are among the many variables that directly affect the final costs of such facilities.

The costs of school building, planning, and construction have undergone a great many changes during the last few years. Cost comparisons by unit cost figures from one district or region to another require detailed

knowledge of the derivation of the figures.* Generally, the unit cost considered is cost per square foot of school building, cost per pupil, or cost per pupil space provided. The cost breakdown for school buildings in the New England area of the United States is presented in Table 44.

Table 44

BREAKDOWN OF SCHOOL CONSTRUCTION COSTS
United States, New England Area

	Elementary Schools Percent of Total			Secondary Schools Percent of Total		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Construction cost	64.4%	74.0%	83.1%	63.0%	74.0%	84.9%
Site development	5.2	10.0	13.3	1.7	9.0	14.5
Architect and engineer fee	3.5	5.0	6.8	5.4	6.0	7.0
Equipment	3.3	8.0	11.9	3.8	10.0	15.6
Other	0.7	3.0	5.0	0.4	1.0	2.4

Source: "What New Schools are Costing: Elementary and Secondary Schools," Nations Schools, Vol. 77, May 1966.

* R. F. Tonigan, "Fallacies of Building Cost Comparisons," American School & University, Vol. 38, November 1965, pp. 59-60. "Thus, we can pinpoint the fact that the unit cost of school construction has continued to increase because labor costs have risen faster than inflation, because more complete schools and colleges are being built, and because persons responsible for maintaining and operating educational buildings better realize the importance of keeping operational costs down.

"Not only are the unit costs of construction increasing but the number of square feet of educational space both per pupil and per community is rapidly increasing. More educational facilities are being constructed to meet the needs of a much broader portion of the population. It is quite possible that the national movement now in progress to provide education to the country's poverty stricken youth will accelerate to such a rate that, by sheer momentum, the new elementary and secondary schools located in economically disadvantaged school districts will be more numerous and more costly structures than normally might be found in average or wealthy communities. . . .

"It is even possible for unit costs to be compared regionally to some advantage, but indiscriminate comparison of unit costs of construction between one district and another or between two or more colleges can be foolhardy and more often than not, it is."

Even within this region, per square foot costs in 1964-65 varied from $9.85 to $21.44 for one and two story elementary schools, and from $12.75 to $17.37 for one and two story secondary schools.

Institutional characteristics such as teacher-pupil ratio, managerial efficiency, and program quality are other major variables that influence costs, apart from the variables directly related to building costs. Studies by various authorities are inconclusive with respect to economies of scale when educational performance as well as costs are taken into account.[94,96,99]*

Analysis of India Field Data. In the study region, schools are operated in both the public and private sectors. In the public sector, the capital investment is mainly by the state government on a precinct or district basis. The education policy is mainly governed by the central and state agencies, and the local authorities operate under the aegis of the state system. In the 18 cities covered in the field studies, it was observed that there was little recent capital investment on school buildings in the public sector, and that the majority of the existing schools were either in buildings erected prior to 1961 or in leased buildings.

The schools are broadly of two levels:†

1. Primary Schools - Grades 1-5

2. High Schools - Grades 6-11

In the public sector, pre-primary schools are practically nonexistent, although in the private sector, there are a few schools in this category.

The available data on capital cost are presented in Table 45. The costs are not adjusted over time and space, but it is apparent that they vary even within one city in one year. This is expected since the unit cost (per pupil place or per square foot) is a function of diverse institutional, design, and budgetary factors.

Available data on the number of schools and enrollment in the 18 cities have been used to measure the level of service, as shown in Table 46.

Information on teachers' salaries in the schools surveyed was available only for primary schools, averaging Rs. 1,365 per teacher on an annual basis. For cost estimation in Chapter V, the all-India ratio of secondary to primary teachers' salaries was applied.‡

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* Also see extensive studies of the determinants of educational expenditures by H. Thomas James, et al., Wealth, Expenditure and Decision-Making for Education, Stanford University Press, 1963, pp. 69-100.

† In 50 percent of the cities, a middle school or a junior high school also exists as an intermediate stage (grades 6-8), but according to the new standards, the education system is primarily at two levels.

‡ Reference 98, p. 47.

Table 45

CAPITAL AND AMO COSTS OF SCHOOLS

City	Year Constructed	Unit Cost of Building (Rs.) Per Sq Ft	Unit Cost of Building (Rs.) Per Pupil Place	AMO Cost Rs. per Pupil Place (1966-67)
Primary schools				
Saharanpur	1967	8.33	883	633
	1967	12.86	2,227	n.a.
	1963	12.00	768	319
Kanpur	1966	10.56	n.a.	n.a.
Varanasi	1960	10.60	n.a.	n.a.
Secondary schools				
Karnal	1964	8.32	n.a.	n.a.
Modinagar	1957	12.63	n.a.	336
Varanasi	1963	12.39	n.a.	n.a.

n.a. = not available.

Source: Field survey.

Table 46

EXISTING LEVEL OF SERVICE FOR REPORTING SCHOOLS
IN 18 CITIES
1967

	Per 1,000 Persons: No. of Schools	Per 1,000 Persons: No. of Pupil Places	Area per Place (sq ft)	No. of Pupils per Teacher
Primary school	0.36	112	12-13	32
Junior high school (or middle school)	0.09	43	n.a.	n.a.
Secondary school	0.03	44	27-31	26

n.a. = not available.

Source: Field survey.

The National Buildings Organisation, in a study of capital costs for school facilities for central government employees, recommended the standards presented in Table 47.

Table 47

STANDARDS FOR GOVERNMENT EMPLOYEE SCHOOLS*

	School Size		
	A	B	C
Enrollment (number of students)	720	480	240
Teaching area per student (sq m)	2.17	2.19	3.27
Total area per student (sq m)	2.39	2.60	3.73
Cost per student (Rs.) (Delhi 1962)	525	630	935
Hostels			
Number of seats	180	120	60
Area per seat (sq m)	5.53	5.56	5.45
Cost per seat (Rs.) (Delhi 1962)	1,340	1,350	1,335

* Building efficiency 67-72 percent.

Source: National Buildings Organisation, Central School Buildings, Report by a Special Committee, 1964, Nirman Bhawan, New Delhi, 1964, pp. 9-12.

The National Buildings Organisation also suggested that the annual maintenance cost should not exceed 1-1/2 percent of the capital cost of buildings for central schools, and that special repairs should not exceed 1/4 percent. This standard is used for calculations in Chapter V.

For estimating the costs of educational facilities in Chapter V, the following standards have been used on the basis of a review of available field data:

Primary School

Area per pupil place	14 sq ft
Capital cost of equipment*	Rs. 155/pupil place
Building cost	Rs. 182/pupil place

Higher Secondary School

Area per pupil place	27 sq ft†
Capital cost of equipment*	Rs. 200/pupil place
Building cost	Rs. 405/pupil place

Hospitals

Size and Cost. New general hospitals are costing more per square foot because of advances in techniques, equipment, and patient care requirements. Geographically, these costs vary widely. Costs per bed show an even wider range. The size and cost of individual hospitals vary considerably, of course, mainly because of differences in design, type of construction, and metropolitan versus nonmetropolitan needs.‡ Larger hospitals are capable of providing a greater range of medical services, containing larger and more specialized equipment and facilities, but they are not in general less expensive in unit costs than smaller hospitals. Table 48 illustrates this point.

Economies of scale in hospital costs are more a function of the service input and output than mere physical scale by building and equipment. Cohen,§ in a multivariate analysis of hospital costs, combining both cost inputs and service outputs, concludes: "It appears that hospitals between 150 and 350 beds are most efficient for ordinary patient care. Larger hospitals might be needed for special services but do not appear to be most efficient for the more or less routine services included in the measure of output."

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* Based on studies of cost of educational facilities, Asian Regional Institute for Educational Planning and Administration, Delhi.

† The field data indicate a range of 27-31 square feet, compared to the standards of National Buildings Organisation 23.6 to 35.2 square feet. Twenty-seven square feet is considered appropriate for purposes of this study.

‡ U.S. Dept. of Labor, Bureau of Labor Statistics, Labor Requirements for Hospital Construction, Bulletin No. 1340, Washington, D.C., 1962, p. 6.

§ Reference 103, p. 355-66.

Table 48

HOSPITAL CONSTRUCTION COSTS PER SQUARE FOOT
UNITED STATES
1961-65

By Number of Stories		By Number of Beds	
1-2 Story		To 100 beds	
High	$46.53	High	$56.12
Median	30.25	Median	30.50
Low	24.04	Low	24.04
Number	28	Number	41
3-12 Story		100-517 beds	
High	$56.12	High	$53.03
Median	35.06	Median	35.03
Low	24.38	Low	23.18
Number	34	Number	18

Source: Engineering News-Record, June 16, 1966.

Analysis of India Field Data. Hospital construction costs were scarce to nonexistent in the 18 cities studied, primarily because few new hospitals have been constructed since 1961. Maintenance and operation costs could not be meaningfully identified for a single hospital or source because of lack of proper accounting form and because of allocation of finances by central and state agencies under different heads.

The majority of the new hospitals constructed during the period were by the Employees State Insurance (ESI) Corporation, chiefly for the benefit of industrial workers. These hospitals are located in urban centers but serve a concentration of industrial workers both within and outside the city or town. A rule of thumb by ESI for hospital services was Rs. 64/worker/year during 1966-67. Table 49 presents the costs of hospitals constructed by ESI in four of the cities surveyed.

The cost per bed among general hospitals decreases as the number of beds increases to 100, the largest number reported. However, the variation in costs per bed is also partly due to differences in design and type of construction, building specifications, and the number of stories and internal fixtures. The data are too meager for meaningful analysis.

Table 49

HOSPITAL COSTS PER BED
(Bareilly 1965 = 100)

City	Year	No. of Stories	Type of Hospital	No. of Beds	Building Cost per Bed (Rs.)
Ludhiana	1965	3	General	20	25,615
Jullundur	1965	3	General	60	12,213
Modinagar	1967	2	General	100	7,266
Varanasi	1965	1	Combined with dispensary	18	3,350

In 1966-67 the number of medical institutions was 285 in the State of Haryana, 126 in urban areas, and 159 in rural areas.* The hospital standards adopted in Haryana were as follows:†

Population Size	Number of Beds
10,000	30
25,000	75
50,000	125
100,000 and above	2 beds per 1,000 population

Table 50 presents hospital standards recommended by the Committee on Plan Projects, Planning Commission, New Delhi.

A committee appointed by Government of India‡ has recommended as standard costs an annual maintenance and operation cost of Rs. 3,000 per

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* Source: Director General of Medical Services, Government of Haryana, Chandigarh.

† These standards are based on the recommendations of the Government of India, Planning Commission, Committee on Plan Projects, Report on General Hospitals, New Delhi, May 1964, p. 182, and the All India Institute of Medical Sciences and are applicable to Punjab and Uttar Pradesh also.

‡ Government of India, Director General of Health Services, Report of the Hospital Equipment Standardization Committee, March 1963, Coimbatore, 1964, p. 91.

Table 50

HOSPITAL STANDARDS
India

	Area per Bed by Hospital Size (no. of beds)						
Number of beds (in-patient department)	10	25	50	100	200	300	500
Area (sq ft)	800	665	500	589	450	373	322

	Area for Outpatient Department			
Attendance per day	200-300	400-600	750-900	1000-1200
Built-up area (sq ft)	8,775	15,465	19,755	22,140

Source: Government of India, Planning Commission, Committee on Plan Projects, Report on General Hospitals, New Delhi, May 1964, pp. 239-240.

bed, and equipment cost of Rs. 1,200 per bed. For estimating costs of hospital buildings, the rule of thumb used is Rs. 25 per square foot for the year 1967.*

The land requirements for different sizes of hospitals are presented in Table 51 as additional information.

Table 51

LAND REQUIREMENTS BY SIZE OF HOSPITAL

Number of beds	10	25	50	75	100	210	300	400
Area (acres)*								
Low	2	5	8	10	15	20	25	35
High	3	7	10	15	20	25	30	45

* Areas given on the following basis: 1/3 covered by hospital buildings, 1/3 residential, and 1/3 open space.

Source: Government of India, Planning Commission, Committee on Plan Projects, Report on General Hospitals, New Delhi, May 1964, p. 176.

* Source: Government of India, Ministry of Health, Architectural Wing, New Delhi.

Fire Protection

Cost Factors. It is generally recognized that the fire department as organized today has a twofold function--fire prevention and fire protection.* Such distinction is of little concern here since this study is concerned with what it costs to provide these services under the actual developed standards.

The quality and requirements of fire protection service in cities vary from country to country and depend mainly on the following:†

1. Nighttime population‡
2. Area served
3. Density of dwelling units
4. Continued receipts of wholesale, retail, and service establishments.

The type of buildings also plays an important role in requirements because predominantly masonry and cement buildings are less hazardous than wooden construction.

The costs of fire protection services by city size were summarized in an early study of 124 cities by Ridley:§

> (a) There is very little relationship between size of city and population per fireman, except that the very largest cities require fewer, and that the cities of Group III require the least number of firemen on the basis of population . . .
>
> (b) on the per capita basis the trend of cost of operation seems to vary directly with the size of city . . .
>
> (c) the cost of operation per fireman seems to be slightly in favor of smaller cities . . . .

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* Clarence E. Ridley, Measuring Municipal Government: Suggested Standards for Measuring the Results of Fire, Health, Police and Public Works Departments, Municipal Administration Service and School of Citizenship and Public Affairs (Syracuse University), Publication No. 4, New York, 1927.

† Reference 28, pp. 331-2.

‡ The distinction between nighttime and daytime population is important as the former is closely related to the number of dwelling units in the city. "A major excess of daytime over nighttime in an area can usually be traced to commercial and industrial activity, a factor that is best treated separately." Reference 28, p. 331.

§ Ridley, op. cit., p. 19.

Relationships between city size and number of fires, expenditures per capita, and percentage of salaries and wages to total fire department expenditures in U.S. cities in 1961 are shown in Table 52. Little correlation has been established, however, between city population size and fire protection expenditures. A study by Hirsch* of 32 city fire departments shows that the "per capita expenditure function for fire protection in St. Louis area is approximated by a parabola whose trough is at a night-time population of about 110,000 . . . The curvilinearity seems to have been conditioned more by the physical size of service areas than by their population size."

Analysis of India Field Data. Of the 18 cities,studied, data were available for only 11 cities. Five cities--Faizabad, Amroha, Bhiwani, Maunath Bhanjan, and Modinagar--did not have fire protection services within the city.

Table 53 presents data on the number of fire calls per 1,000 population in 10 cities. The higher numbers of fire calls are in the more industrialized and commercialized cities: Phagwara, Jullundur, Patiala, Kanpur, and Saharanpur. For example, Phagwara is the smallest city but has the highest figure, 0.52 per 1,000 population, and it is highly industrialized.

From field observations, it is evident that the development of fire protection service in a city, including its branches, is closely related to availability of adequate water supply. In the study region, the requirement of water supply for fire fighting is considered to be the water necessary for a continuous stream at full pumping capacity for 100 minutes. On a population basis, this is one gallon per capita to be available at all times for fire fighting.†

The development of fire protection service in cities is mainly guided by national standards of a uniform scale based on area coverage and population served. The general standard recommended by the Standing Fire Advisory Committee "on improvements of fire services in states" is one Fire Fighting Unit (FFU)‡ for an urbanized area of 4 square miles accommodating 50,000 population. An FFU is to be provided for every 50,000 population, or part thereof, up to 300,000; thereafter, an FFU is to be provided for every 100,000 population. Twenty percent of the above is maintained as reserve.

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* Reference 36, p. 238.

† See Schedule I, Minutes of the 8th Meeting of Standing Fire Advisory Committee, Madras, January 1960, mimeograph unpublished.

‡ "A fire fighting unit should be normally taken as having a pumping capacity of 500 gallons per minute. This can conveniently be split up into more than one unit of smaller capacities if necessary."

Table 52

NUMBER OF FIRES AND FIRE DEPARTMENT EXPENDITURES BY CITY SIZE
U.S., 1961

Number of Building Fires per 1,000 Population

Population Group	Number of Cities Reporting	Lowest	Lower Quartile	Median	Upper Quartile	Highest
Cities over 500,000	18	1.9	2.9	3.5	3.8	6.7
250,000-500,000	25	1.2	3.1	3.9	4.9	6.5
100,000-250,000	63	0.7	2.4	3.7	4.3	6.7
50,000-100,000	158	0.7	2.4	3.5	4.5	25.7
25,000-50,000	303	0.1	2.1	3.3	4.5	12.9

Fire Department Expenditures

Population Group	Number of Cities Reporting	Population of Cities Reporting (000)	Fire Department Expenditures Per Capita		Salaries and Wages as % of Total
			Salaries and Wages	Total	
Over 500,000	17	15,389	$9.57	$10.38	92.2%
250,000-500,000	23	8,160	8.67	9.51	91.2
100,000-250,000	66	9,676	8.97	10.12	88.6
50,000-100,000	129	9,029	8.41	9.65	87.1
25,000-50,000	282	9,876	6.84	8.15	83.9
10,000-25,000	618	9,731	4.74	6.06	78.2
All cities over 10,000	1,115	61,861	7.99	9.08	88.0

Source: The International City Manager' Association, The Municipal Year Book, 1962, Chicago, Ill.

Table 53

NUMBER OF FIRE CALLS - 1967

City*	Population (000)	Number of Fire Calls	
		Total	Per 1,000 Population
Kanpur	1,070	350	0.33
Varanasi	573	105	0.18
Bareilly	304	44	0.14
Jullundur	266	119	0.45
Saharanpur	212	70	0.33
Patiala	145	56	0.39
Jagadhri-Yamunanagar	132	30	0.23
Karnal	81	25	0.31
Phagwara	48	25	0.52

* There are no fire protection facilities in Faizabad, Amroha, Bhiwani, Maunath Bhanjan, or Modinagar. Data for Ludhiana, Gorakhpur, and Hapur are not available.

Source: Field survey.

Capital Costs. Capital costs include the building, equipment, and vehicles. Building costs were not easily quantifiable because the fire stations were mostly housed in part of an office building complex of the local authorities Capital equipment costs are not locally recorded since the city departments acquire equipment mainly through state allocations. From the limited data available over a five-year period, it appears that the minimum capital cost per capita for building, equipment, and vehicles ranges from Rs 0.21 to 0.33 per year in city sizes of 50,000 population and above. This unit cost is used for calculations in Chapter V, the lower range being applied to cities of 250,000 population and over.

Studies in the region indicate the life expectancy of equipment and vehicles as approximately 8 to 10 years.*

Current Expenditures. Operating and maintenance costs of fire protection in 11 cities are presented in Table 54. Per capita costs in rupees vary from a low of 0.11 to a high of 0.42, excluding the figure 0.66 for Ambala Town Group, which is exceptional because of duplication of expenditures by separate entities in the town group. Four of the highest per capita expenditure figures correspond with the cities earlier shown to have the largest number of fire calls: Patiala, Phagwara, Kanpur, and

* Source: Chief Fire Officer, Delhi Fire Services, Delhi, India.

Table 54

FIRE PROTECTION EXPENDITURES
1967

City*	Population (000)	Expenditures (Rs.) Total Amount (000)	Total Per Capita	Salaries and Wages Amount (000)	Salaries and Wages Per Capita	Salaries and Wages % of Total
Kanpur	1,070	278	0.26	235	0.22	85%
Varanasi	573	144	0.25	137	0.24	95
Bareilly	304	47	0.15	36	0.12	76
Jullundur	266	n.a.	n.a.	163	0.61	n.a.
Saharanpur	212	48	0.23	30	0.14	63
Ambala (Town Group)	202	133	0.66	87	0.43	65
Patiala	145	60	0.42	40	0.28	66
Jagadhri-Yamunanagar	132	33	0.25	31	0.23	94
Karnal	81	9	0.11	7	0.08	78
Hapur	59	8	0.14	7	0.12	86
Phagwara	48	13	0.27	9	0.18	68

n.a. = not available.

* There are no fire protection facilities in Faizabad, Amroha, Bhiwani, Maunath Bhanjan, or Modinagar. Data for Ludhiana and Gorakhpur were not available.

Source: Field study.

Saharanpur. The low figures are for two cities in the population group 50,000-100,000, a size class in which the remaining four cities studied have no fire protection services. Expenditure on salaries and wages ranges from 63 to 95 percent of total expenditures.

For estimation of annual maintenance and operation costs in Chapter V, it is appropriate to use average costs for those cities that have the most developed services. The weighted mean AMO cost for the cities included (Kanpur, Varanasi, Saharanpur, Patiala, Jagadhri, and Phagwara) is Rs. 0.26 per capita.

Garbage and Refuse Disposal

General Considerations. Garbage and refuse service includes the regularly scheduled pick-up, collection, and disposition by a sanitary agency of solid waste materials resulting from the operation and maintenance of

households and other establishments. The main materials handled are garbage, ashes, and rubbish.*

The amount of refuse† produced varies greatly from residences to commercial and industrial establishments. Generally, it can be stated that the average unit cost of refuse collection service is affected by the following five major groups of variables:‡ (1) amount or quantity of service, (2) quality of service, (3) service conditions affecting input requirements, (4) labor and equipment price level, and (5) state of technology and productivity. The quantity and type of refuse per capita (or household) determine the basic physical structure of the service unit at the city level.

Almost every basic local government service unit has a variety of quality dimensions. The quality dimension, insofar as refuse collection and disposal service is concerned, is in regard to the type of beneficiary. Since refuse collection combats many health hazards, refuse collection quality would include the frequency, care, and reliability of the removal service; cleanliness, location, and nature of pick-ups, i.e., whether separation into garbage and trash is required; and use of specialized collection equipment instead of open trucks for transportation of the refuse collected.

A variety of physical, human, political, and legal factors bear upon the input requirements.§ Clearly, the most important are land uses and density within the city.** The haul length, vehicle capacity, and managerial arrangements are other factors which influence service conditions Collection and disposal technologies undergo changes over the years.

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* The American Public Works Association defines garbage, ashes, and rubbish in the following way: "Garbage is the animal and vegetable waste resulting from the handling, preparation, cooking, and serving of foods . . . Ashes are the residue from the burning of wood, coal, coke and other combustible material . . . . Rubbish consists of a variety of both combustible and non-combustible waste material . . . 'Trash' is considered to be synonymous with rubbish." Committee on Refuse Collection of the American Public Works Association, Refuse Collection Practice, Cushing-Malloy, Ann Arbor, Mich., 1958, pp. 13-17.

† In this section, no distinction is made between garbage and refuse, and the term "refuse" whenever used includes both.

‡ See Werner Z. Hirsch, "Cost Functions of an Urban Government Service: Refuse Collection," The Review of Economics and Statistics, Vol. XLVII, No. 1., February 1965, pp. 87-92.

§ Hirsch, op. cit.

** Reference 28, pp. 340-44. In this study of St. Louis and 87 municipalities in St. Louis County, the major independent variables considered include nighttime population, density of dwelling units per square mile, number of persons per dwelling unit, and number of wholesale, retail, and service establishments.

Changes from the simple use of landfills to the sophisticated disposal techniques using such machines as incinerators and grinders eventually have effect on costs.

Several studies have been made on refuse collection and refuse disposal separately to determine cost differentials and focus interest on scale economies and break-even points. Hirsch states: "Per capita expenditures for refuse collection are not significantly related to size of community, after effects of other factors are partialled out."*

The Committee on Refuse Disposal of the American Public Works Association in a discussion of selecting disposal methods states: "Operating costs vary widely, depending on the type of refuse, type of plant and extent of its mechanization, the labor and efficiency of management."† On comparative costs the APWA Committee mentions, "It is difficult to compare disposal costs from various cities. In fact, it is sometimes difficult to compare costs from year to year in the same city."‡

However, as a comparison of costs among three near-complete disposal methods--sanitary landfills, incineration, and composting--the following relative economies result:

> Initial capital costs for sanitary landfills, including costs of site acquisition and preparation, are roughly one-fourth to one-half of those for central incineration. The modern, fully mechanized composting plant costs about what an incineration plant does.
>
> Operating costs for sanitary landfills are approximately one-third to one-half of those for incineration unless hauling costs for landfills are excessive.§

The data presented in Table 55 amplify this further. From Figure 14, note that in per capita costs of sanitary landfill operation in 200 U.S. cities in 1959, the mean and median costs fall irregularly over the population range to 100,000. The wider variation of maximum per capita cost in cities up to 25,000-50,000 suggests that the stage or scale of facility development in this range has more direct influence than population size on per capita costs.

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* Reference 36, p. 239.

† American Public Works Association, Municipal Refuse Disposal, APWA Research Foundation Project 104, Public Administration Service, Chicago, Ill., 1961, pp. 53-86.

‡ Op. cit., p. 66.

§ Op. cit., p. 67.

Table 55

COST PER TON OF INCINERATION AND LANDFILL OPERATIONS BY DEPARTMENTS, NEW YORK CITY
January-June 1960

	Incineration* (853,164 tons received, 656,808 tons processed)		Land Fills (875,162 tons received & processed)
	Cost per Ton Received ($)	Cost per Ton Processed ($)	Cost per Ton Received and Processed ($)
Bureau personnel			
Direct labor	$1.94	$2.52	$0.41
Servicing vehicles, plant security and housekeeping	0.53	0.68	0.11
Administration and supervision	0.36	0.47	0.13
Paid absences	0.57	0.74	0.13
Subtotal	$3.40	$4.41	$0.80
Operating supplies	0.13	0.17	0.04
Department overhead			
Motor vehicle maintenance	0.09	0.12	0.22
Plant and equipment maintenance	0.23	0.30	0.03
General administration	0.21	0.28	0.05
Total	$4.07	$5.29	$1.16

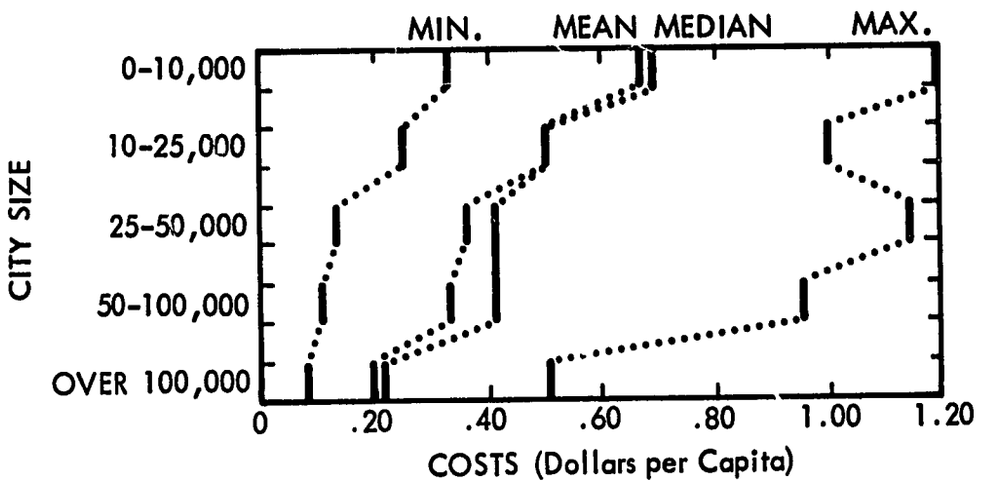
Note: Does not include amortization, utilities, and fringe benefits. Detail may not add to totals due to rounding.

* Costs include residue hauling only; residue disposal included in landfills.

Source: American Public Works Association, Municipal Refuse Disposal, Chicago, Ill., 1961, p. 346.

Figure 14

SANITARY LAND-FILL OPERATIONS, PER CAPITA COSTS, U.S., 1959



SOURCE: American Public Works Association, Municipal Refuse Disposal, Second edition (Chicago: Public Administration Service, 1966), Figure 145, p. 363.

Analysis of India Field Data. Garbage and refuse collection and disposal are essentially a local government service in the study region. The expenditures of city-operated refuse collection and disposal include current expenditures plus equipment purchased in a specific year, 1966-67. Some minor items that could be charged to the refuse collection and disposal department, such as office space and parking facilities for equipment, are probably not included in the figures, thus tending to make expenditures appear somewhat lower than they actually are.

In all but one city, Amroha, refuse is picked up by a city-operated system.* Because of a lack of underground sewerage in a majority of the cities, the disposal of night soil is also included in the city-operated refuse disposal system.†

Refuse disposal is generally by landfills, and composting is by manual labor. Mostly, garbage is used for composting, and rubbish is used

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* In Amroha, city government has little expenditure for refuse pick-up; it is primarily done by private collectors because of a historical social custom.

† Separate vehicles such as tankers and animal driven carts are provided for pick-up of night soil and generally it is restricted to a particular section of the refuse disposal department.

for landfills, both inside and outside city limits.* There are no reliable data on amounts of refuse collected or disposed, since no records are kept; however, rough estimates can be made from the number of vehicle trips, capacity, and composting sales. Because of the variety of administrative arrangements, contract systems, and area coverage by different systems, there is little comparability among cities.

The vehicles used for pick-up range from animal driven carts to tankers, and tractor trailers, and open and closed trucks. Capacities of these vehicles are:

	Cu Ft
Animal driven carts	70-200
Tankers†	70-200
Tractor trailers	100-150
Trucks	140-180

Expenditure data are presented in Table 56. Total per capita rupee expenditures clearly fall in three groups, averaging 4.2, 1.2, and 0.3, with no relation to city size (Table 57). This suggests that per capita expenditure is influenced more by the level of development of the service than by population size. In the higher range, the number of employees per 1,000 population is high. In cities of medium and low per capita ranges, data on number of employees are available only for one city each, but these figures are much lower. This is consistent with the proportion of salaries and wages to total expenditures: 91 percent or more in cities with high per capita expenditures, 57 to 89 percent in the medium group, and 33 to 80 percent in cities with low expenditures. Without adequate data for statistical analysis, it is difficult to compare levels of services in the three categories, but by comparing the number of employees per 1,000 population, it appears that in the cities where per capita expenditures are high, the level of service may be somewhat better. The weighted mean expenditure for the 10 cities with high and medium per capita expenditures, Rs. 2.7 per capita, is used in the cost estimates of Chapter V.

During the years 1966-67, it appears that there were relatively more capital expenditures in the groups that had medium and low per capita expenditures than in the group that had high per capita expenditures. Generally this could be considered as the formative stage of the service where investments on capital equipment are usually high.

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* In a few cities, night soil is also used for composting but it is mostly garbage or a combination of the two. Rubbish is generally used for landfills and reclamation of low-lying land within corporate limits. In almost all the cities, private collectors are also encouraged to dump "malba" (rubbish) in specified areas to speed up land reclamation.

† Tankers for night soil ranged from animal driven cart to motor vehicle.

Table 56

GARBAGE AND REFUSE DISPOSAL EXPENDITURES*
1967

City	Population (000)	Expenditures (Rs.) Total Amount (000)	Total Per Capita	Salaries and Wages Amount (000)	Salaries and Wages Per Capita	Salaries and Wages % of Total
Varanasi	573	2,856	4.98	2,797	4.88	98%
Ludhiana	323	274	0.85	n.a.	n.a.	n.a.
Bareilly	304	255	0.84	189	0.62	74
Jullundur	266	343	1.29	203	0.76	59
Gorakhpur	216	717	3.32	668	3.09	93
Saharanpur	212	94	0.45	57	0.27	60
Patiala	145	211	1.45	120	0.83	57
Faizabad	92†	483	5.25	457	4.96	95
Ambala City	90	45	0.50	34	0.38	77
Karnal	81	15	0.19	10	0.12	65
Jagadhri‡	66	20	0.30	8	0.12	40
Maunath Bhanjan	60	209	3.49	194	3.23	93
Hapur	59	238	4.03	n.a.	n.a.	n.a.
Phagwara	48	10	0.20	8	0.16	79
Modinagar	36	68	1.88	59	1.64	87

n.a. = not available.

* Data pertains to local government operated services. Separate services in cantonments exist under the cantonment boards and these are excluded. Data for Hapur was not available and Bhiwani and Amroha reported no expenditures.

† Estimate by local authority.

‡ Jagadhri city only.

Source: Field survey.

Table 57

LEVELS OF PER CAPITA GARBAGE AND REFUSE DISPOSAL EXPENDITURES FOR SELECTED INDIAN CITIES 1966-67

	Per Capita Expenditures (Rs.)	No. of Employees per 1,000 Population	Salaries & Wages as % of Total Expenditures
High per capita expenditures			
Faizabad	5.2	4.7	96%
Varanasi	5.0	4.6	98
Hapur	4.0	n.a.	n.a.
Maunath Bhanjan	3.5	4.0	91
Gorakhpur	3.3	2.9	94
Medium per capita expenditures			
Modinagar	1.9	n.a.	89
Patiala	1.4	0.5	57
Jullundur	1.3	n.a.	62
Ludhiana	0.8	n.a.	n.a.
Bareilly	0.8	n.a.	75
Low per capita expenditures			
Ambala City	0.5	n.a.	80
Saharanpur	0.4	0.3	75
Jagadhri	0.3	n.a.	33
Karnal	0.2	n.a.	50
Phagwara	0.2	n.a.	80

n.a. = not available.

Source: Table 55.

Police Protection

Social and Physical Factors. The social and physical factors that influence expenditures for police protection are many. Bollens* in his study of factors affecting local government expenditures mentions the following variables:

1. Nighttime population†
2. Total miles of street. The presumption is that more patrolmen are needed when more street mileage is to be protected.
3. Nighttime population density per square mile. It is generally recognized that congestion breeds crime.
4. Percent of nighttime population under 25 years of age. Juvenile delinquency seems to pose serious police problems in many metropolitan areas.
5. Combined receipts of wholesale, retail, and service establishments.†
6. Quality of police protection.

To these might be added the extent and quality of street lighting, and the nature of curfew and other local laws.

A regression analysis of 62 counties and the City of St. Louis in the St. Louis city-county area showed that increases in per capita expenditures for police protection are associated mainly with increases in service level and per capita assessed valuation. An interesting by-product of the service-quality index is the indication that smaller communities have difficulty in providing adequate police protection.[28] Recognizing the various local factors which have an important influence upon police protection costs, it is difficult to identify or account for the variations in level of services from one police force to another.‡

A study of 1,226 cities of over 10,000 population in the United States indicates that (1) expenditures per capita are generally higher as the number of people in population group increases, and (2) more than 80 percent of per capita expenditures are accounted for by salaries and wages (Table 58). The share of expenditures for personnel increases steadily with city size.

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* Reference 28, p. 336.

† See the preceding discussion on fire protection.

‡ Reference 39. In their study of 12 Massachusetts towns, Isard and Coughlin arbitrarily apportion police protection costs among dwelling units, industrial activities, and commercial activities.

Table 58

POLICE DEPARTMENT EXPENDITURES BY CITY SIZE
United States, 1961

Population Group	Number of Cities Reporting	Population of Cities Reporting (000)	Expenditures: Total Per Capita ($)	Expenditures: Salaries and Wages Per Capita ($)	Expenditures: Salaries and Wages % of Total
Over 500,000	18	16,328	$17.26	$15.81	91.6%
250,000-500,000	23	8,160	11.20	9.80	87.5
100,000-250,000	65	9,524	10.47	9.02	86.1
50,000-100,000	133	9,248	10.38	8.84	85.2
25,000-50,000	298	10,329	9.11	7.60	83.4
10,000-25,000	689	10,761	8.36	6.83	81.8
All cities over 10,000	1,226	64,350	11.70	10.22	89.8

Source: International City Managers' Association, The Municipal Year Book 1962, Chicago, 1962.

Analysis of India Field Data. In the study region, police protection services in cities are mainly governed at the state level. The state police department provides police service in cities through precinct or district stations. Most police stations provided in cities cover areas which extend beyond the corporate limits. Data obtained mainly encompass current expenditures in the urban areas, although at the ministerial (clerical) and supervisory level, some outlying areas are covered.

Data on police department expenditures and personnel are presented in Tables 59 and 60. Per capita rupee expenditures vary from a low of 1.93 to a high of 2.78* showing no correlation by city size. Salaries and wages account for 95 percent or more of per capita expenditure except for Karnal, at 85 percent.

* Varanasi and Faizabad are excepted. These cities of religious importance have police protection needs that are different from those of other cities.

Table 59

POLICE DEPARTMENT EXPENDITURES
1967

City*	Population (000)	Expenditures (Rs.) Total Amount (000)	Total Per Capita	Salaries & Wages Amount (000)	Salaries & Wages Per Capita	Salaries & Wages % of Total
Kanpur	1,070	2,939	2.75	2,928	2.73	99%
Varanasi	573	2,001	3.49†	2,001	3.49	100‡
Bareilly	304	676	2.24	646	2.13	96
Gorakhpur	216	552	2.56	525	2.43	95
Patiala	145	403	2.78	394	2.72	98
Faizabad	88	320	3.64†	320	3.64	100‡
Karnal	81	183	2.26	157	1.93	85
Maunath Bhanjan	60	116	1.93	116	1.93	100‡

* Data for other cities not available.
† High figures because of special details; religious fairs and excess floating population create need for large police force.
‡ Data on maintenance costs reported as nil.

Source: Field study.

Policemen per 1,000 population vary from 0.8 to 1.8, with an average of 1.4, excepting Varanasi and Faizabad. Significantly, the cost of police protection in rupees per acre shows clustering within the range 45-60, with the exception of Karnal at 75. Omitting Varanasi and Faizabad, the average cost per acre, used in Chapter V, is 49.

Table 60

POLICE PROTECTION SERVICES
AND COSTS PER CORPORATE AREA
1967

City	No. of Policemen Total	No. of Policemen Per 1,000 Population	Acres (000)	Corporate Area Density (persons per acre)	Corporate Area Cost per Acre (Rs.)
Kanpur	1,504	1.4	64.6	17	45
Varanasi	1,343	2.3*	18.2	31	110*
Bareilly	243	0.8	12.8	24	53
Gorakhpur	372	1.7	9.6	22	58
Patiala	254	1.8	8.3	17	48
Faizabad	209	2.4*	7.8	11	41
Karnal	98	1.2	2.4	33	75
Maunath Bhanjan	76	1.3	1.9	31	60

* High figures; see footnote on Table 59.

Source: Field study.

A substantial part of the capital expenditures, especially equipment and vehicles, are governed by the centralized system. These were usually not identifiable with city expenditures because of allocations and replacements on an annual or recurrent basis from the state department. There were few capital outlays on buildings in the period considered. The majority of the buildings were either constructed prior to 1961 or used on a lease basis. However, the new building complex (1966-67) for the police station in Maunath Bhanjan could be considered typical of capital expenditures for a police station for the population group 50,000-100,000. The cost per policeman works out to Rs. 1171.*

Municipal Administration

There is a substantial body of literature on municipal finances in both developed and developing economies. The primary concern in many studies has been to analyze statistical evidence on relationships between municipal finances and size of city, densities, income levels, property valuations, and other variables. Population size as a factor influencing municipal finances has been most controversial. As we have seen in Chapter II, on the one hand evidence has been brought out that per capita municipal costs and revenues are influenced by population size, but on the other hand, some studies have denied any significance to size.

* Maunath Bhanjan - 1967 prices.

A recent compilation, covering 75 percent of the urban local bodies in India made by the Committee on Augmentation of Local Finances, shows that per capita municipal income and expenditures rise with increase in population size of urban centers.* Table 61, showing per capita incomes and expenditures arranged by size of urban centers, is derived from the Committee's report. The figures pertain to all municipal services and functions.

Table 61

NUMBER OF URBAN LOCAL BODIES AND PER CAPITA REVENUE EXPENDITURES AND ORDINARY INCOME BY CITY SIZE 1960-61

Size Category	Number of Urban Local Bodies	Per Capita Revenue Expenditures (Rs.)	Per Capita Ordinary Income (Rs.)
100,000 and over	107	14.95	16.40
50,000-100,000	134	12.71	14.07
20,000-50,000	436	12.49	13.28
10,000-20,000	514	11.15	11.74
5,000-10,000	483	10.93	11.47

Source: Government of India, Ministry of Health and Family Planning, Report of the Committee on Augmentation of Local Finances in India, New Delhi, 1965.

There is greater uncertainty when individual elements of expenditure are examined. In this section, we examine only the element of general administration, which includes supervision, collection of taxes, levies and tolls, inspection, nontechnical surveys, and other financial responsibilities.

The functions of general administration are delegated to urban local authorities under the State Municipal Acts. Types of local government units in the 18 cities include the corporation, municipality, notified area committee, and cantonment board. The duties and powers of the local bodies vary between states and with the nature and size of the local government unit, introducing differences in administrative costs. For instance, the Punjab Municipal Act provides that the municipalities "shall unless relieved by the State Government maintain a sufficient police establishment." No such provision is made in the Uttar Pradesh Municipal

* Government of India, Ministry of Health and Family Planning, Report of the Committee on Augmentation of Local Finances in India, New Delhi. 1965.

Act. This function, if taken upon by the municipalities in Punjab, would increase the administrative costs significantly compared to those of Uttar Pradesh. The same would be true if some taxes were leviable or levied by certain municipalities and not by others. Differences in administrative costs might also arise on account of the nature and magnitude of capital works, level of services provided, and special locational features of the urban centers. Faizabad may be cited as a town where additional administrative functions connected with religious congregations around the year add to the general administration costs.

Field data for expenditure on general administration are given in Table 62, which shows (1) percentage of expenditure on general administration to total municipal expenditure and (2) per capita expenditure on general administration. It may be mentioned at the outset that the percentage and per capita expenditures on general administration are uniformly higher for urban centers of Punjab compared to Uttar Pradesh. Different scales of pay of the municipal personnel and differences in the obligatory functions of the municipal bodies in the two states partly explain the variations in expenditure.

If we disregard these regional differences, it is observed from the table that percentage of expenditure on general administration tends to decline with the increase in city size. An exception to this seemingly general trend is the city size group of 100,000-250,000, in which general administration claims 45.6 percent of the total municipal expenditure. Aside from this category, the highest administrative expenditure of 45.2 percent is noted for the city in size group 20,000-50,000, followed by nearly equal percentages for 50,000-100,000 and 250,000-500,000 size groups (14.8 and 15.0 respectively).

No clear pattern is observed for per capita expenditure on general administration. In view of the inconclusive evidence for the field cities, no attempt is made in Chapter V to include general administration expenditures in the cost estimates.

Data from a larger sample, however, show a clearer trend in general administration expenditures (Table 63). This table shows that the per capita expenditures as well as percentages of expenditure on general administration increase with the decline in the city size group. Thus while municipal expenditure as a whole has a positive correlation with city size, expenditure on general administration shows an inverse correlation. This appears reasonable because in the smaller centers, the main functions of local bodies are collection of taxes and levies, and in the absence of major capital works, the share of expenditure on administration is appreciably higher. If total volume of municipal expenditure is any indication of scale, then there are evidently scale economies in the expenditure on administration in cities of over 100,000 compared to smaller cities.

As a general conclusion, it may be said that the share of administration expenditure in total municipal expenditures is generally higher for smaller cities, compared to cities in larger population categories. As the functions of local bodies become diversified and complex, per capita expenditure on administration vis-a-vis other areas declines.

Table 62

PERCENTAGE AND PER CAPITA EXPENDITURE ON GENERAL ADMINISTRATION FOR SELECTED CITIES*

Size Category and City	General Administration Expenditure as % of Total		Per Capita General Administration Expenditure (Rs.)	
	1961-62	1966-67	1961-62	1966-67
1,000,000 and over				
Kanpur	6.9	7.9	3.16	3.43
Average	6.9	7.9	3.16	3.43
500,000-1,000,000				
Varanasi	9.7	8.8	1.72	1.96
Average	9.7	8.8	1.72	1.96
250,000-500.000				
Ludhiana	13.2	13.8	2.63	2.82
Jullundur	13.4	16.6	1.84	2.89
Average	13.3	15.0	2.25	2.85
100,000-250,000				
Gorakhpur	6.7	6.2	1.14	1.10
Ambala	35.2	48.6	5.66	8.92
Patiala	48.7	43.7	5.25	7.50
Average	42.3	45.6	5.40	8.04
50,000-100,000				
Faizabad	9.7	9.6	1.77	2.43
Karnal	26.2	22.1	2.72	3.13
Amroha	17.8	15.0	1.60	1.78
Bhiwani	28.4	29.6	2.82	3.87
Maunath Bhanjan	8.1	9.4	1.40	1.44
Hapur	12.5	12.0	2.05	2.99
Average	15.3	14.8	2.07	2.59
20,000-50,000				
Phagwara	47.2	45.2	4.90	6.58
Average	47.2	45.2	4.90	6.58

* Data for other field survey cities not available.

Source: Local authorities.

Table 63

GENERAL ADMINISTRATION EXPENDITURES, PERCENT AND PER CAPITA BY CITY SIZE 1960-61

Size Category	General Administration Expenditure as % of Total		Per Capita General Administration Expenditure	
	Punjab (%)	Uttar Pradesh (%)	Punjab (Rs.)	Uttar Pradesh (Rs.)
100,000 and over	17.1%	12.6%	4.20	3.37
50,000-100,000	27.6	17.9	4.54	3.99
20,000-50,000	24.1	29.4	5.62	6.41

Source: Govt. of India, Ministry of Health and Family Planning, Report of the Committee on Augmentation of Local Finances in India, New Delhi, 1965.

IV RELATIONSHIPS BETWEEN INDUSTRIAL LOCATION, SIZE OF CITY, AND INFRASTRUCTURE REQUIREMENTS

This chapter fulfills a number of objectives:

1. Evidence is presented on the relationships between industrial location and size of city in order to perceive if there are tendencies for certain industries to locate in cities of particular sizes.

2. Coefficients of infrastructure requirements for selected Indian industries are developed directly from the field data. On the basis of these coefficients, industries of different use-intensities of infrastructure are identified.

3. The analyses for objectives 1 and 2 are combined in order to form what we visualize as urban choices for industrial location.

4. The above information is keyed to the fundamental objective of developing appropriate sets of industries for different city sizes These sets furnish the basis for the estimation of infrastructure costs in Chapter V.

Industrial Location and Size of City

The purpose of this section is to analyze the relationships between industrial structure and size of city, primarily to examine their application for developing industry mixes that have potential for different sizes of urban centers.

Relationships Identified in Other Studies

Except for two major contributions by Duncan[109] and Morrissett,[117] locational analyses to date have produced little evidence in the area of distinguishing ubiquitous types of industries from what may be singularly representative of particular sizes of urban center. Most discussions have been devoted to presenting a two-tier classification of industries--i.e., those which have least freedom in their locations, and those which are footloose in character. Their locational attributes have been explained in relation to the classical factors of production, in terms of relative costs of transporting raw materials to industry and products to consumers, and in terms of agglomeration and external economies. Even this classification is being eroded with greater application of science and technology, and industries which formerly were locationally sensitive are no longer

so. In fact, the whole spectrum of industrial location under varied impacts is becoming less responsive to the classical and neoclassical locational models, which might suggest that the locational behavior of industries is being influenced to a great degree by noneconomic phenomena. Lösch's* prologue that the actual location may not necessarily coincide with the rational location is one of the many expressions to indicate the qualified validity of locational theories.

Duncan† has analysed the U.S. Census data, 1950, to show industry composition differences with size of place, by using an "Index of Dissimilarity," and has extended the exposition to what he calls a system of urban hierarchy. The hierarchic pattern, he concludes, "is largely accounted for by the tendency of extractive, processing, and local service industries to relate inversely to city size and the complementary tendency of fabricating and non-local service industries to relate directly to city size. The conclusion must be phrased in terms of the particular industry classification used, however." Morrissett[117] has keyed his contribution to establishing quantitative relationships between sporadic and ubiquitous industries with city size, and for this purpose has utilized Alexandersson's‡ k values (ratios which show, for different industries, the proportion of industry activity required as a minimum to supply a city's own population with goods and services).

Mention may also be made of a pioneering study[113] on industrial location trends in India, in progress now. Preliminary results of the research, which are focussed on the distribution patterns of new industrial units in centers of different sizes, show that 64.4 percent of the total industrial units licensed between 1952-1964 were located in cities of 100,000 and over. The share of the metropolitan cities (having a population of 1 million and more) alone was 41.4 percent of the total. On the basis of these facts, the study has raised a number of questions on policies related to industrial location and urban development.

Comparative Analysis by Type of Industry--India and United States

Our analysis starts with the underlying notion that centers of different sizes are not the locations of the same type of industries; rather, there are differences, not uncommonly consistent, in the industrial structure

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* August Lösch, The Economics of Location, Yale University Press, New Haven, Conn., 1954, p. 4. He further elaborates this point to say that "it would be dangerous to conclude that what is must also be rational since otherwise it could not exist, and that any theoretical determination of the currect location would therefore be superfluous."

† Reference 109, p. 66.

‡ Gunnar Alexandersson, The Industrial Structure of American Cities: A Geographic Study of Urban Economy in the United States, University of Nebraska Press, Lincoln, 1956.

according to city size. This does not imply that the entire gamut of analysis is focussed on structuring a two axis size-location model which would be an oversimplification of a complex issue. On the contrary, the analysis recognizes that size of city is only one of the important variables influencing industry locations, and that any homogeneity in the pattern of industry distribution is the cumulative effect of a large number of factors including the levels of economic development, regional spread of natural resources, labor market, infrastructure, and specific market potentials. What has been attempted here is to present data, both of the study region and of the United States, from which certain clear and other less clear relationships between the size of urban centers and industrial activity could be established. In the sense that such an effort makes it possible to identify the types of activities characterizing different city sizes, it is a step forward in the literature on spatial economics specifically related to the different levels of population aggregation.

India Locational Analysis. At this stage, we introduce Table 64 giving population and factory employment in different city size categories, for Uttar Pradesh and Punjab.* The table indicates the comparative status of the industrial structure of the two states, and also serves as a basis for detailed analyses of the distribution of employment in the individual industries. Population figures in the table pertain to the Census year 1961, while manufacturing employment data have been compiled from the List of Registered Factories, 1965, covering factories with 10 or more employees if using power, 20 or more if without power. Since no major shifts in geographical distribution of population took place between 1961-65, it is assumed that the use of two different bases would not cause any variance in the coefficient of industrialization.†

The aggregate population for Punjab and Uttar Pradesh in the different size categories is quite evenly distributed, with a low degree of skewness toward the smallest size group of 20,000-50,000. In contrast to the total regional picture, the pattern of distribution for Punjab shows a much higher population concentration in the two smallest size groups, both accounting for 61 5 percent of the total urban population in size centers of 20,000 and over. Uttar Pradesh presents a relatively more uniformly distributed urban population, with the exception of low percentage in size category of 50,000-100,000 and a high percentage in centers of 500,000 and over. The latter accounts for 27.2 percent of total effective urban population.‡

Analysis indicates that there is little similarity between the distribution of industrial employment and urban population in the two states.

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* Data for Punjab include Haryana.

† The coefficient of industrialization is the simple ratio

$$\frac{\text{Percent of Industrial Employment in the Size Group}}{\text{Percent of Population in the Size Group}}.$$

‡ Effective urban population here refers to the total population living in urban centers of 20,000 and more.

Table 64

POPULATION DISTRIBUTION AND FACTORY EMPLOYMENT
ARRANGED BY CITY SIZE
Punjab and Uttar Pradesh

	Punjab					Uttar Pradesh				
Size Category of Urban Centers	Total Population	% of Population in Each Size	Industrial Employment	% of Industrial Employment in Each Size	Coefficient of Industrialization	Total Population	% of Population in Each Size	Industrial Employment	% of Industrial Employment in Each Size	Coefficient of Industrialization
500,000 and over	---		---			2,135,315	27.2	113,241	55.3	2.03
250,000 - 500,000	620,616	20.4	45,372	41.6	2.03	1,477,419	18.8	15,093	7.4	0.39
100,000 - 250,000	551,013	18.1	4,243	3.9	0.22	1,546,833	19.7	24,381	11.9	0.60
50,000 - 100,000	887,089	29.2	45,726	42.0	1.44	1,114,062	14.2	27,103	13.2	0.93
20,000 - 50,000	982,257	32.3	13,659	12.5	0.39	1,578,234	20.1	25,007	12.2	0.61
Total	3,040,975	100.0	109,000	100.0	1.00	7,851,863	100.0	204,825	100.0	1.00

Sources: Census of India 1961, Vols. XIII and XV, Part II-A, 1962; List of Registered Factories for Uttar Pradesh and Punjab, 1965.

The incidence of manufacturing employment when aggregated for the two states is substantially greater in the largest size category; parallels the population percentage of the next size group 250,000-500,000; and then shows no regularity. The aggregate weight of coefficients for Punjab and Uttar Pradesh points out a strong tendency for the industrial activities to agglomerate in larger sized urban centers, as also the "overpopulation" of other size groups relative to their industrial employment. The table also brings out the fact that size group 50,000-100,000 has expanded its industrial base much in advance of the size groups 20,000-50,000 and 100,000-250,000. This is reflected in coefficients of industrialization near or above 1.0 for this group.

When the data for the two states are examined separately, a number of other interesting facts are noticed. First, it is observed that the level of manufacturing activity, as measured by the percentage of manufacturing employment to total population, is substantially higher in Punjab (3.58) than in Uttar Pradesh, where it is 2.61. Second, it appears that in Punjab, the industrial progress that took place in the post-plan period was largely shared between 50,000-100,000 and 250,000+ categories of urban centers. The same trend is observable for the State of Uttar Pradesh where the largest size group has a coefficient of 2.03, followed by 0.93 for the category 50,000-100,000.*

The weakest group in Punjab with respect to industrial growth is 100,000-250,000, which incidentally is a configuration of urban centers having essentially administrative functions.† A similar situation is presented by centers of 100,000-500,000 in Uttar Pradesh, which have functioned as administrative centers. Incidentally, of the 14 centers which constitute this major group in Uttar Pradesh, only three have been functionally classified as "manufacturing" centers, others being predominantly "service" or "trading" communities.‡

It is apparent from the above analysis that there is a big hiatus between the development of industry and that of urban centers. It further seems that industry growth in the largest size categories of urban centers has bypassed the next largest category. This is brought out by the coefficients of industrialization which drop substantially in the next largest

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* Smaller towns of Punjab (20,000-50,000) received a major share of unorganized manufacturing during this period.

† Ambala, Patiala, Chandigarh, and Ferozepur are the administrative towns grouped here; the last two were very close to a population of 100,000 and that is why thay have been grouped in this class.

‡ Asok Mitra, A Functional Classification of India's Towns, Part II: Inventory of Classified Towns, Institute of Economic Growth, Delhi, paper submitted to the All India Seminar on Population, March 12-14, 1964, 98 pp.

size categories, both in Uttar Pradesh and Punjab.* In fact, the whole orbit of manufacturing in the medium sized centers is generally limited to what may be a semblance of industrialization. Without further deliberating on the nature of problems that arise in the context of unbalanced growth, we now examine the type of industries which characterize the various sizes of urban centers. This is shown in Table 65 which gives the location quotients of individual industries in different sizes of urban centers.†

Location quotients indicate the degree of ubiquity or skewness of the individual industries, to show industry/city size characterization. In other words, these show the relative dispersion/concentration of each industry vis-a-vis the population distribution in urban centers of different sizes. The location quotient for purposes of our analysis denotes the following ratio:

$$\frac{\text{No. of persons employed in industry x in size group } \underline{a}}{\text{Total no. of persons employed in industry x in size groups } \underline{a}, \underline{b}, \underline{c} \ldots \underline{n}} \div \frac{\text{Population in size group } \underline{a}}{\text{Total population in size groups } \underline{a}, \underline{b}, \underline{c} \ldots \underline{n}}$$

This ratio of ratios reduces to:

$$\frac{\text{Percentage of industry } \underline{x} \text{ employment in city size group } \underline{a}}{\text{Percentage of population in city size group } \underline{a}}$$

Thus, taking Punjab as an example, if the percentage of employment in the dairy products industry in the size category 20,000-50,000 to total employment in the dairy products industry is 60.6, and percentage of population to total in the same size group is 32.3, then the location quotient will be 1.88 for this industry (60.6 ÷ 32.3). A preliminary interpretation of this figure would mean that the size group 20,000-50,000 has a relatively greater proportion of dairy industry than what is consumable locally, and

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* This is obviously not a permanent structural feature. The anticipated advance of many 50,000-100,000 size cities into the next size class will significantly increase the incidence of manufactures in the 100,000-250,000 category. This size class therefore has particular interest as a transitional range for industrial development.

† Preceding the computation of quotients, we developed a table showing the distribution of factory employment in individual industries by city size categories. This was arrived at by adding the factory employment of individual industries (3-digit) in each size group, and then working out the percentage from the total for all sizes. Location quotients were directly derived from this table.

Table 65

LOCATION QUOTIENTS FOR SELECTED INDIAN INDUSTRIES BY CITY SIZE, 1965

Industry Code	Industry Description	Punjab: Location Quotients in Sizes 250,000-500,000	100,000-250,000	50,000-100,000	20,000-50,000	Uttar Pradesh: Location Quotients in Sizes 500,000-1,000,000	250,000-500,000	100,000-250,000	50,000-100,000	20,000-50,000
20	Food Manufacturing Industries, Except Beverage									
202	Dairy products	---	---	1 35	1 88	1.21	0.22	1 96	0.31	0.99
203	Canning and preserving of fruits and vegetables	0.70	---	2.93	---	0.39	1.72	1.34	1.62	0.37
205-1	Flour mills)	1.05	1.84	0.66	0.68	1.14	0.16	0.50	1.54	1.69
205-2	Rice mills)									
206	Bakery products	0.09	---	---	3.04	2.85	0.54	0.63	---	---
207	Sugar factories and refineries	---	---	2.66	0.69	0.03	0.06	0.50	0.92	3.77
208	Cocoa, chocolate & confectionary	---	---	---	---	2.11	---	1.45	0.99	---
209-2&3	Edible and hydrogenated oils)	1.59	0.45	1.01	0.92	1.17	0.57	0.68	0.57	1.79
209-8	Cold storage and ice-making)									
21	Beverage Industries*	---	---	3.42	---	0.81	0.12	1.23	1.01	1.86
214	Soft drinks and carbonated water	---	---	---	---	3.68	---	---	---	---
22-220	Tobacco Manufacturers	---	---	---	---	0.58	---	3.98	---	0.28
23	Manufacture of Textiles									
231-1	Cotton textiles	2.67†	0.06	.20	0.29	2.92	0.09	0.21	0.41	0.45
231-3	Woolen textiles					2.64	---	1.15	---	0.27
232	Knitting mills	4.86	---	0.03	---	3.59	0.08	---	---	0.04
233	Cordage, rope and twine	---	---	3.42	---	2.39	---	---	2.46	---
239	Textiles not elsewhere classified	---	5.52	---	---	2.22	0.18	0.76	0.49	0.72
239-1	Cotton ginning and pressing	0.05	0.11	1.18	1.93	1.98	---	1.90	0.18	0.30
24	Manufacture of Footwear, Other Wearing Apparel & Made-up Textiles	0.13	---	3.33	---	3.66	---	0.02	---	---
25	Manufacture of Wood Except Furniture	0.34	0.18	3.01	0.03	0.48	0.18	0.35	4.46	0.67
26-260	Manufacture of Furniture & Fixtures	1.10	2.87	0.70	0.16	0.30	2.69	0.39	0.16	1.54
27-271	Manufacture of Paper & Paper Products	0.11	0.24	3.20	---	2.17	1.13	0.25	0.44	0.42
28-280	Printing, Publishing & Allied Industries	2.87	1.20	0.63	0.04	1.43	0.98	2.11	0.04	0.03
29	Manufacture of Leather and Fur Products Except Footwear									
291	Tanneries and leather finishing	3.00	---	---	1.20	3.41	0.04	---	0.16	0.19
293	Leather products except footwear	2.59	---	---	1.46	2.73	1.09	---	0.36	---

Table 65 (concluded)

Industry Code	Industry Description	Punjab: Location Quotients in Sizes 250,000-500,000	100,000-250,000	50,000-100,000	20,000-50,000	Uttar Pradesh: Location Quotients in Sizes 500,000-1,000,000	250,000-500,000	100,000-250,000	50,000-100,000	20,000-50,000
30-300	Manufacture of Rubber Products	2.19	0.01	1.36	0.48	0.30	4.27	0.44	0.17	0.03
31	Manufacture of Chemicals & Chemical Products									
311	Basic industrial chemicals	3.55	0.22	0.41	0.36	1.52	1.51	0.49	0.04	0.99
313	Paints, varnishes and lacquers	1.05	0.04	1.88	0.70	‡	---	---	---	---
319	Miscellaneous chemicals	---	---	---	---	0.81	1.23	2.21	0.15	0.45
33	Manufacture of Non-Metallic Mineral Products									
331	Structural clay products	1.24	1.04	1.17	0.67	1.61	---	---	3.95	---
332	Glass, and glass products	0.10	0.06	3.32	---	0.25	0.21	0.16	4.67	0.98
333	Pottery, china and earthenware	---	0.23	1.68	1.45	1.49	---	0.43	2.42	0.83
339	Non-metallic mineral products not elsewhere classified	0.56	---	0.62	2.18	0.85	1.17	2.78	---	---
34	Basic Metal Industries									
341-3	Castings and forgings	2.10	0.30	0.80	0.88	2.31	0.30	0.68	0.92	0.27
342	Non-ferrous basic metal industries	0.99	2.51	0.87	0.28	2.64	0.13	0.98	0.22	0.17
35-350	Manufacture of Metal Products Except Machinery & Transport Equipment	3.41	0.20	0.54	0.34	1.37	0.82	1.63	0.65	0.28
36-360	Manufacture of Machinery Except Electrical	3.76	0.42	0.68	0.28	1.97	0.79	1.07	0.42	0.23
37-370	Manufacture of Electric Machinery, Apparatus, Appliances & Supplies	0.51	0.62	1.80	0.77	1.50	1.22	0.53	1.28	0.37
38	Manufacture of Transport Equipment									
382	Railroad equipment, including wagons and coaches	2.42	0.23	1.22	0.34	1.85	0.06	2.41	0.07	---
383	Motor vehicles and parts	---	---	---	---	2.29	1.28	0.70	---	---
384	Repair of motor vehicles	1.67	1.35	0.51	0.82	1.54	0.68	0.80	0.65	1.02
385	Motorcycles and cycles	4.71	---	---	0.46	§	---	---	---	---
386	Aircraft	---	---	---	---	3.45	---	---	0.44	---
389	Transport equipment n.e. elsewhere classified	---	---	---	---	0.87	4.06	---	---	---
39	Miscellaneous Manufacturing Industries									
391	Professional, scientific and controlling instruments	0.44	4.50	0.33	---	3.18	0.15	0.53	---	---
392	Photographical and optical goods	---	---	---	---	3.68	---	---	---	---
393	Watches and clocks	---	---	---	---	---	5.32	---	---	---
395	Musical instruments	---	---	---	---	3.68	---	---	---	---
399	Industries not elsewhere classified	2.07	0.39	1.29	0.39	1.49	0.65	1.21	0.47	0.83

Note: Industry codes used here have been adapted from the Classification of India Industries, as published in the Annual Survey of Industries, Vol 1, 1961, Appendix II, by the Central Statistical Organisation, Calcutta, India.

* Beverage industries do not include soft drinks, which is a subcategory.
† Cotton textiles category includes woolen textile manufacturing for Punjab.
‡ Included in miscellaneous chemicals
§ Include in transport equipment "not elsewhere classified."

Source: List of Registered Factories, Uttar Pradesh and Punjab, 1965.

with the qualifications noted in the next paragraph, dairy industry is an "export" industry as far as this size group is concerned.*

Interpretation of location quotients must be qualified particularly because of the aggregation of populations by size of place in the denominator. This masks regional patterns of industry as well as variance among individual cities in each size class. Granting this limitation, location quotients in this form can be examined as tentative indicators of market orientation of consumer products, and of linkages among producer or intermediate goods. If population is taken as a first approximation of market potential, consumer product location quotients near 1 for all city sizes would be an indication that the industry is market-oriented or makes important use of a widespread resource. Conversely, it can be said that city size groups having a location quotient value much higher than 1 for a given industry must export a substantial proportion of the industry's products to other markets, either directly or as intermediate inputs to end-products or services for those markets.

To further explain: quotients equal or close to 1 in each of the four size categories in Punjab and the five size categories in Uttar Pradesh would signify a high degree of ubiquity or widespread location, since the industrial employment in such a case would be proportionate to the population in each size category. In order to have a coefficient of 1 or close to 1, the factory employments would have to be in the same proportion as the population percentage. The more the quotients move away from 1, the greater would be the case of accentuated concentration of particular industries in specific size groups.

As a guideline to delineating industrial groups characterizing various size categories, we have made use of the following criteria, allowing adjustments in marginal cases:

1. Quotients of more than a value of 3 would signify a very high degree of size characterization.

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* The concept of location quotient has been extensively used by Florence and Hoover in explaining problems of industrial location. More recently, Wilbur R. Thompson has provided a critique of the original concept, and to circumvent the ambiguity in the use of the concept of location quotient has suggested the "coefficient of spatial dispersion" as a better measure of locational intensity. The location quotient as evolved here is somewhat different from that developed by Florence and Hoover, in the sense that they have related employment in individual industries to total gainful employment as a base, while we have related employment in specific industries to the population base. See Edgar M. Hoover, "The Measurement of Industrial Localization," The Review of Economics & Statistics, XVIII, November 1936, pp. 162-71; P. Sargent Florence, Investment, Location and Size of Plant, University Press, Cambridge, England, 1948; and Wilbur R. Thompson, "The Coefficient of Localization: An Appraisal," Southern Economic Journal, January 1957, pp. 320-325.

2. Quotients between the values of 2 and 3 may signify either a lack of decisive pattern or low-moderate degree of concentration.

3. Ubiquity would be signified if (a) the highest quotient value is not more than three times the lowest observed values, and (b) the industry is represented in at least three size groups in Punjab and four size groups in Uttar Pradesh. Thus quotients having values 1.05, 1.84, 0.66, and 0.68 in the four size categories (rice and flour milling in Punjab) represent a typical case where this industry is common to all sizes of urban centers.

Three typical cases of ubiquity, high concentration, and lack of size characterization are illustrated in Figure 15.

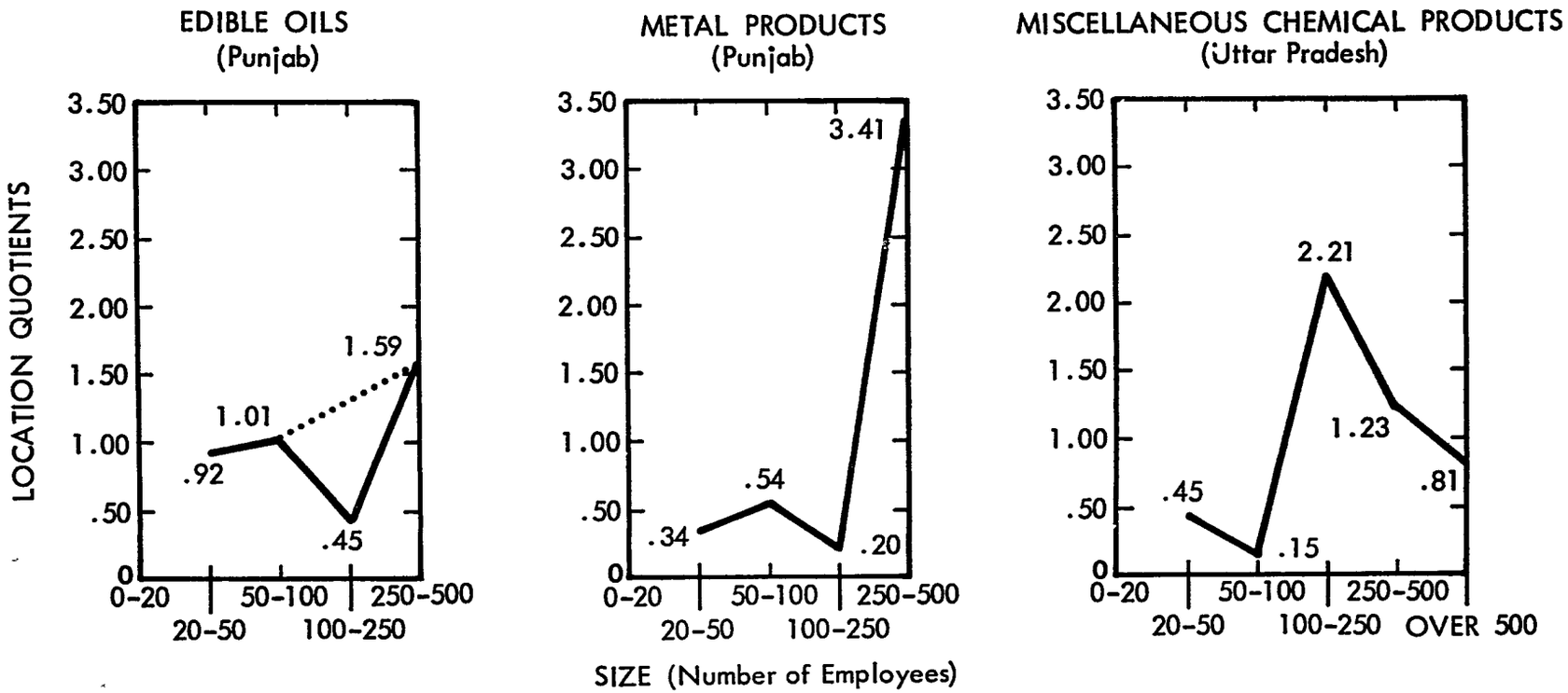
In analyzing Table 65, use has also been made of the field data that help to explain industry/city size relationships. This is a measure to minimize the limitations imposed by the nonavailability of detailed industry data at the 4-digit level of classification. The lack of detailed data is particularly felt for categories of chemical, metal, and machinery manufacturing industries, which constitute the main core of the industrial activities of the two states.

Based on the above stated criteria, the following industry/size relationships can be identified. For analytical convenience, we are designating urban centers of size category 20,000-100,000 as small, 100,000-250,000 as medium, and 250,000 and over as large.

High Incidence in Different Sizes as Measured by a Location Quotient of 3 and Over. Table 65 shows a high incidence of dairy, bakery, sugar, beverages, cordage-rope-twine, cotton ginning, footwear, wood, paper, glass, and pottery industries in the smaller sized urban centers of Punjab, and of beverage, sugar, wood, structural clay products, glass, and pottery industries in Uttar Pradesh. The quotients for these industries (excepting structural clay products) in other size groups are below 1, further signifying a strong orientation to small urban centers. It is observed, however, that cotton ginning, wood, paper, pottery, and sugar industries are heavily drawn to specific nodes of resource availability, all being either weight-losing or perishable. Economically and rationally, their locations are determined by the main consideration of resource distribution. The role of small towns as collection centers for raw materials of the region is a factor in the location of these industries. The consideration that explains the location of cordage-rope-twine industry is either nearness to the resource or nearness to the consuming centers; in the former case, the raw material used may be grass, while hessian may be the raw material if this product is manufactured close to the markets. In Punjab, this industry is a characteristic of small centers, while in Uttar Pradesh, small and large centers share the total employment in this industry. The high incidence of bakery, beverages, and footwear industry in the small centers of Punjab is attributed more to historical reasons, rather than to size advantage or any other locational consideration. No technologically advanced industrial activity is associated with the smallest urban centers.

Figure 15

TYPICAL CASES OF INDUSTRIAL CONCENTRATION AND DISPERSION



Example 1: Ubiquity, Common to all Size Classes

Example 2: Concentration, High Size Characterization

Example 3: Lack of Consistent Size Pattern

The medium size group of urban centers is structurally weak in industry, as has been pointed out earlier. In Punjab, there is a concentration of scientific measuring and controlling instruments in this size category,* the same being a characteristic of large sized urban centers of Uttar Pradesh. No other clear relationships are seen for this size group. It is when we move to the next higher category of urban centers (over 250,000) that the industrial composition becomes heterogeneous, as well as typifies a greater degree of manufacturing operations compared to processing. Obvious illustrations are the metal and machinery group, motorcycles and bicycles, aircraft parts, musical instruments, and specialized equipment such as photography items, watches, and clocks. In addition, other industries oriented to this size are cotton textiles, knitting, basic industrial chemicals, soft drinks, tanneries, and rubber products This structure indicates specialization, extended market area, a certain degree of technology needed for manufacturing, and other economies associated with size. It is these features which differentiate a large from a small city.

Medium Incidence in Different Sizes as Measured by a Location Quotient Between 2 and 3. As stated earlier, this category is somewhat nebulous, since it may indicate either a low degree of concentration of particular industries or a lack of any decisive pattern of locational significance. Judged within this context, it is observed that in the smaller sized urban centers, industries which show low-moderate degree of concentration are nonmetallic mineral products, pottery, cordage-rope-twine, canning and preservation of fruits, and sugar refineries--incidentally, all relatively inflexible in location. Perishability or weight reduction play an overwhelmingly important part in location of these industries. The manufacture of railroad equipment and miscellaneous chemicals have location quotients ranging between 2 and 3 for medium size urban centers in Uttar Pradesh. There is far greater industrial diversification in the large urban centers: the significant concentration of leather products, motor vehicle parts, big sized castings and forgings, cocoa and chocolate, and chemicals is instructive for our analysis.

Industries Characteristic of All Sizes of Urban Centers. Conforming to the twofold test of ubiquity, a number of industries showing widespread dispersion in different size groups can be identified from Table 65. These are flour and rice milling, ice making and cold storage, structural clay products, repair of motor vehicles, castings and forgings of different sizes, nonferrous metal products, electric appliances, and

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* Several urban cities of the field region are characterized by a high degree of specialization in a relatively narrow group of industries. Examples are hosiery in Ludhiana; rubber footwear in Jullundur; brass utensils and goods in Jagadhri and Moradabad; mathematical, surveying and drawing instruments in Roorkee; scientific instruments in Ambala; and glass bangles in Firozabad.

beverage industries. An analysis of the characteristics of these industries would show that ice making and cold storage, and repair of motor vehicles are highly localized types of activities, in the sense that the final consumption of their products and services are linked primarily with the area of production. In these cases, the means of transferability is extremely low. Likewise, structural clay products involve heavy transportation costs, and tend to meet limited areal demands. It is also customary to find that in order to meet at least the demands of a nonbasic* nature, nearly all sizes of urban centers have casting and forging operations, and also the manufacturing of electric household appliances and other similar equipment. This is also valid for various kinds of nonferrous metal products.

In this pattern of dispersion, a significant point to note is that manufacturing operations for the same product differ in scale, technology, and management with variation in size of urban centers. The particular instance of casting and forging may be explained here. Field visits in Uttar Pradesh and Punjab showed the existence of casting operations fairly well spread out in different sizes of urban centers. The main differences with respect to these operations related to: (1) sizes of castings, (2) quality and finish of the product as a function of different grades of patterns and moulds, proportions of basic materials used, and skill applied; (3) variability of the market area; and (4) management and organization of the foundries. The same type of scale and technology differences would be noticeable for other kinds of industrial activities when the size of area of operation changes.†

Judging from the characteristics of the above industries, it is quite apparent that these essentially are related to the community's basic requirements. Their occurrence in all sizes, with the above-stated stipulations, indicates that there are no inhibitions imposed by the size of urban centers on their location. In fact, these may constitute a minimum industrial structure of any size town.

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* The term nonbasic has been used to denote the activities serving the local market. These are synonymous with what are described as city-filling, secondary, or residentiary activities. See Charles M. Tiebout, The Community Economic Base Study, Supplementary Paper No. 16, published by the Committee for Economic Development, New York, December 1962.

† This variation among individual products in a single industrial "class" underscores the need for greater detail in a definitive analysis of location factors. In reviewing the use of location quotients in this chapter, both Richard Eckaus and Lowdon Wingo have stressed the need for careful interpretation of these aggregate measures. It would appear that the cluster-seeking technique used in Chapter II could be very productively applied to this field of location analysis, provided that suitably defined and detailed data categories are available or can be developed.

From the foregoing analysis, it is possible to structure an illustrative classification showing industries characteristically related to various city sizes. Since the effort is to relate the analysis to prospective growth of industries, which takes into account many other factors, we incorporate the same as part of the last section of this chapter.*

A dynamic view of future interactions between city size and growth of industry must incorporate evidence of several kinds. We have been confined above to a cross-section view for a recent period, rather than examining trends over time, because of lack of earlier comparative data. Even as locational trends within the region become visible, they will be subject to marked new influences and shifts due to the very volume of increased manufacturing activity to be launched in the next decade.† For inferences on long term locational factors, it is worth examining city-size patterns in economies where much wider lists of manufactures can be scrutinized in detail.

City Size Distribution of U.S. Industries. Here, as in Chapter III, our purpose in comparative analysis is to find underlying structural contrasts and parallels that may be instructive for future development. The dangers of "development by analogy" have recently been pointed out.‡ However, to the degree that comparative analysis is able to expose either inherent logic or historical coincidence in existing urban locational patterns, industrialists and developers starting in a fresh environment can apply a fresh logic. We cannot analyze in depth here the complex of factors influencing the city-size distribution of U.S. industries, but the classification presented in Appendix B and summarized below may help lay the groundwork for such analysis. It will also draw attention to the wide gamut of specific industries which have options for location in different size cities.

The principal empirical evidence on relationships between size of city and composition of manufactures in the United States is in the volume

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* While available evidence on industry/city-size relationships has been presented in the preceding pages, there are many industries whose rationale for location in particular sized urban centers has been difficult to obtain. As should be obvious, finding explanations for the location of each industry was neither the objective of this study nor a possibility.

† A national increase of 259 percent in value added by manufacture from 1965-66 to 1975-76 has been projected. See Government of India, Perspective Planning Division, Planning Commission, Draft Fourth Plan Material and Financial Balances, 1965-66, 1970-71 and 1975-76, September 1966, p. 25. A reappraisal of these targets was undertaken by the Planning Commission in November 1967.

‡ Eugene Staley and Richard Morse, Modern Small Industry for Developing Countries, McGraw-Hill Book Company, New York, 1965, p. 136.

Metropolis and Region, cited previously, by O.D. Duncan and others.[109] * The findings of this major work most relevant for our present purpose involve analysis of location quotients for the principal industrial activities performed in Standard Metropolitan Areas (SMAs) in 1950.† The location quotient as applied in the Duncan study is the ratio

$$\frac{\text{Percent of SMA labor force in a given industrial category}}{\text{Percent of U.S. labor force in the given industrial category}}.$$

The industrial categories used by Duncan are broad. Individual manufacturing industries were grouped through inspection of an input-output table into six categories, cross-classifying three stages of resource intensity and two market stages as illustrated below:

Production Stage	Market Stage: Nonfinal	Market Stage: Final
First stage resource user	Grain mill products	Meat products
	Structural clay products	Fruit and vegetable canning
Second stage resource user	Blast furnaces and steel mills	Bakery products
	Textile mills	Apparel and knitwear
Resources of indirect significance	Fabricated metal products	Footwear, except rubber
	Machinery	Watches and clocks

The study presents location quotients for each SMA, as well as average quotients for six SMA size classes and the nonmetropolitan United States.

Inspection of Duncan's array of location quotients reveals high variance among SMAs within SMA size classes, and also among size classes. The

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* See also references 108, 119, and Gunnar Alexandersson, The Industrial Structure of America Cities: A Geographic Study of Urban Economy in the United States, University of Nebraska Press, Lincoln, 1956.

† A Standard Metropolitan Area is a county or group of contiguous counties which contains at least one city of 50,000 inhabitants or more. Contiguous counties are included if they meet specified criteria defining an essentially metropolitan character and economic as well as social integration with the central city. In New England, data on cities and towns together with population density criteria are substituted for county measures.

marked degree of nonuniformity is a clear warning against any view of "symmetry" or regularity between city size and manufacturing structure. Given this variance, average location quotients for city size classes are worthy of note in only a few instances. These are suggestive, however.

As expected, nonmetropolitan United States has a location quotient above one (1.40) for first stage resource processors, nonfinal. The 38 SMAs of 100,000-150,000 population in 1950 have high average quotients for first stage final production (1.57) and second stage nonfinal or intermediate manufactures (1.47). The 36 SMAs in the next size group, 150,000 - 250,000 population, shift markedly from resource processing to manufactures in which resources are of indirect use, for nonfinal (1.33) and final (1.31) markets. A narrower size group, 21 SMAs of 250,000-300,000 population, has a wider progression of substantial quotients, advancing from 1.14 for first stage final manufactures to 1.21 for second stage nonfinal, 1.23 for second stage final, and 1.34 for indirect resource users in nonfinal markets.

A gap in manufacturing strength in the SMA size class 500,000-1,000,000 is suggested by the Duncan location quotients. Average quotients for the 19 SMAs in this class are noticeably above one (1.24) only for first stage final manufactures and the much smaller category of indirect resource users for final markets (1.20). The 14 SMAs in the largest size class, over 1,000,000, show much wider manufacturing diversification, with average quotients of 1.43 for second stage final producers, 1.44 for indirect resource nonfinal producers, and 1.39 for indirect final production.

A broad progression or, in Duncan's term, hierarchy of manufacturing structure is seen in the above review of location quotients by metropolitan size. The following focus on a much more detailed breakdown of manufactures sharpens some of the contrasts as well as the regularities that cut across this structural pattern.

We have used the percentage distribution of employment in U.S. 4-digit industries in different city size groups as of 1954 as the basis for establishing locational categories by city size. Details of the classification criteria and lists of industries in ten categories are presented in Appendix B, including location quotients for each industry by city size group. The location quotient is the ratio

$$\frac{\text{Percentage of industry } i \text{ employment in size of place } j}{\text{Percentage of total U.S. population in size of place } j},$$

and is thus directly analogous to the measure used in Table 65. Where employment distribution in itself did not provide a clearcut criterion, as in the case of ubiquitous industries (Category V below) or those with high incidence in the smallest cities (Category VII), the location quotient was used as the criterion for classification.

Except for Category VI, which focuses on small cities outside metropolitan areas, the classification which follows is based on city size irrespective of whether the city is inside or outside of a metropolitan area. However, the percentage of each industry's 1954 employment within metropolitan areas is included on the industry lists in Appendix B as a further aid to the study of locational incidence.*

We summarize below the principal types of industry that are distinctive in each location category, noting production and market characteristics that are relevant to questions of locational choice and levels of infrastructure use.

I. Very High Incidence in Large Cities (500,000 or more). Industries with very high incidence in large cities are of three types: food and beverages, apparel and other nonstandardized consumer products, and printing. Industries of the first type--prepared meats, flour mixes, confectionery products, beer and ale, and flavorings--decline in incidence with remarkable regularity from large to medium-size and smaller places. Very high location quotients for many clothing industries reflect in particular the dominance of New York. Printing and publishing industries reflect forward linkages to commercial users and engender noteworthy backward linkages: the only chemical or machinery industries with very high large city incidence are printing ink and printing trades machinery!

II. High Incidence in Large Cities (500,000 or more). Nearly half the industries in this category are similar to category I types: food, apparel, and printing. Two important types are added: chemical end products and fabricated or assembled light metal products. Chemical end products in this group are paints and varnishes, toilet preparations, cleaning and polishing preparations, glue, and gelatine. Metal products include metal house furniture, lighting fixtures, fabricated pipe and fittings, valves and fittings (except plumbing), mechanical measuring instruments, and scientific instruments. Metal stampings, tin cans and other tinware, and plating and polishing are also prominent, implying direct

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* See Robert M. Lichtenberg, One-Tenth of a Nation, Harvard University Press, 1960, pp. 31-70 and 252-271, for a classification of U.S. manufacturing industries in 1954 by "dominant locational characteristic," showing the share of the New York Metropolitan Region in total U.S. employment in each industry. Classificatory factors used in the New York study are: external economies; transport costs, creating locational pulls toward either sectional or national markets; supply and costs of skilled and unskilled labor; and inertia. Of 446 industries examined, 91 were unclassified. Comparison of Appendix B with the New York study classification suggests alternative explanations or research leads for numerous industries, particularly those associated with transport costs and inertia.

linkages for use with many of the consumer end products manufactured in this city size group.

Virtually all products having very high or high incidence in large cities are compact and light in weight, with transport costs very low relative to value added by manufacture. This product characteristic permits shipment to regional or national markets, contributing to the strong position of major cities as distribution centers for such industries.

The relatively high labor intensity of operations required in manufacture of category I and II products is also evident. These industries are among the highest in number of employees per unit of value added.

III. High Incidence in Medium Cities (100,000-499,999) and Substantial Incidence in Smaller Cities (10,000-99,999). Machinery industries, conspicuously absent from categories I and II, have much higher incidence in medium and smaller cities. Category III includes machine tools, computing and related machines, refrigeration machinery, and motors and generators. Important food product industries in this category are meat packing plants, fluid milk and other products, flour and meal, and bread and related products. Other heavy industries with high incidence in medium-size cities include tires and inner tubes, copper rolling and drawing, plumbing fixtures and fittings, and structurals and ornamental work.

IV. High Incidence in Smaller Cities (10,000-99,999) and Substantial Incidence in Medium (100,000-499,999). Basic producer goods including metals, machinery, and transport equipment are especially prominent in cities of 10,000 to 99,999. Basic metals include steel works and rolling mills, foundries, forgings, and wire drawing. Machinery and electrical equipment include farm machinery (except tractors), construction and mining machinery, special purpose and general industry machines, internal combustion engines, pumps and compressors, transformers, and electrical appliances. The city subclass 50,000 to 99,999 has location quotients of 3.19 for motor vehicles and parts, and 2.14 for ship building and repairing.

V. Wide Incidence in All Size Cities, (a) Over 2,500 and (b) Over 10,000 Population. Industries with location quotients of 0.75 or more for all city size classes, but no quotient equivalent to the criteria for high incidence in any single class, meet the test of wide incidence in all size cities, with floors of (a) 2,500 and (b) 10,000 population. Not surprisingly, this category displays the widest industrial heterogeneity among the nine locational categories. Thirteen major industry groups are represented.

Important metal, machinery, and electrical industries having wide city size distribution include nonferrous foundries, heating and cooking equipment, sheet metal and wire work, bolts, nuts, washers and rivets, metalworking and food products machinery, special dies and tools, conveyors, power transmission equipment, wiring devices and supplies, and radios and related products. Machine shops, a prominent service industry, are also central to this category. In ten of the industries just cited, 75 to 85 percent of industry employment in 1954 was within metropolitan areas. About 90 percent of employment in the other three industries was in SMAs.

By contrast, the metropolitan hare of most consumer nondurable manufactures having wide city size distribution was from 52 to 66 percent. Among these are the largest consumer product industries in this locational category: men's and boys' clothing n.e.c., dresses at dozen price, women's and children's underwear, upholstered household furniture, house furnishings, and sporting and athletic goods. The metropolitan employment share in these industries corresponds directly to the metropolitan share of total population, 56 percent, contrasting significantly with the 85 to 95 percent metropolitan share of employment in those apparel industries which have very high large city incidence.

In interpreting these locational contrasts, it is to be noted that apparel industries which have wide incidence in all size cities have higher labor use per unit of value added, and lower hourly wages, than those apparel industries which are highly concentrated in large cities. Wage differentials are an important factor in these locational differences. Apparel and household product industries which are well distributed in all size cities are also characterized by lower value added, relative to transport costs, than are the specialty or brand apparel and consumer chemical products which have high incidence in large cities. This suggests closer market orientation of consumer goods with high transport costs relative to value added.

Neither the consumer products nor the varied metal-working and machinery industries in Category V can be said to require a "minimum" or "critical" size city. Consumer industries in this category appear able to operate without benefit of external economies provided by metropolitan status. Higher metropolitan incidence for the multicomponent metal and machinery manufactures in this category, on the other hand, can be associated with advantages of external economies and proximity to purchasing and distribution agencies.

VI. <u>High Incidence in Small Cities (10,000-49,999) Outside Metropolitan Areas</u>. Industries prominent in small, nonmetropolitan cities are of two main kinds: transport-sensitive resource processors, reducing the weight, bulk and/or perishability of major raw materials; and low wage, labor-intensive manufactures. Agriculturally based industries include canned and frozen fruits and vegetables, poultry dressing, creamery butter, concentrated milk and cottonseed oil mills. Forest-based industries

are pulp, paper, paperboard and building paper mills, plywood, wooden boxes, and wood furniture (not upholstered). Pressed and blown glassware, clay refractories, and cut stone and stone products complete the resource-based industries in this category.

Textile mills make their first prominent appearance in this city size group: cotton yarn, cotton and synthetic broad-woven fabric, and seamless hosiery mills. Footwear and men's dress shirt and nightwear industries are also substantial employers in small, nonmetropolitan cities.

VII. High Incidence in Smallest Cities (2,500-9,999). Hosiery, knitwear, and selected men's apparel including separate trousers and work shirts continue the importance of textile and apparel manufactures in the smallest as well as small cities. Differences between these two locational categories are not pronounced. Many industries which meet the nonmetropolitan small city criteria of Category VI have higher location quotients in the smallest cities, of 2,500-9,999 population. Of note are aircraft engines, tractors, truck and bus bodies: the first two almost entirely in metropolitan areas, but bodybuilding distributed exactly in proportion to the distribution of population between metropolitan and nonmetropolitan areas.

VIII. Wide Incidence in Nonurban as Well as Urban Places.* Category VIII industries are perhaps the most ubiquitous with respect to size of place, tending to nonurban locations but too few in number to establish clear locational characteristics. Fluid milk, textile finishing (except wool), fertilizers, and metalworking machinery attachments suggest the diversity of this small array of manufactures.

IX. High Incidence in Nonurban Places.* Much clearer in significance are those industries with predominantly nonurban locations, divided in Appendix B between metropolitan and nonmetropolitan locations. Six of these industries have over 50 percent employment inside standard metropolitan areas, and 17 industries have over 50 percent employment outside.

The high incidence of basic chemicals and chemical intermediates in nonurban places is the most striking feature of this locational category. Inorganic chemicals, organic chemicals, synthetic fibers, explosives, and synthetic rubber are major industries having 57 to 75 percent employment in places of less than 2,500, or quotients of 1.39 to 1.83 for such locations. In contrast, no basic chemical industries meet the criteria for urban locational categories. The chemical industries just cited include substantial nonmetropolitan as well as metropolitan employment. Their

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* Consistent with the principal U.S. Census of Population criterion for defining "urban," an urban place is one with population of 2,500 or more, and nonurban one with less than 2,500.

employment percentages within SMAs in 1954 were, in decreasing order: synthetic rubber - 89 percent; organic chemicals - 75 percent; inorganic chemicals - 61 percent; explosives - 50 percent; and synthetic fibers - 34 percent.

To basic chemicals, hydraulic cement and aluminum rolling and drawing must be added as heavy industries with high nonurban incidence. Cement exactly matches the 56 percent metropolitan share of population in employment distribution, while aluminum rolling is somewhat above at 66 percent employment inside SMAs. These locational patterns document the tendency of heavy process industries to choose plant sites some distance removed from urban population centers, to meet special requirements of space, materials and process control, transport, waste disposal, and safety.

Resource-based food, wood, and clay product industries complete the nonurban location category.

Size of place distributions of 30 industries in 1954 did not fall within the criteria established to define locational categories. Several of these industries displayed other regularities in location by size of place, while the rest showed little locational consistency. Location quotients for these unclassified industries may be examined in list X of Appendix B, Table B-2.*

Summary Findings. Our locational taxonomy, to conclude, has revealed great diversity in the relationship of industries to size of place. The study of U.S. industries at the 4-digit level of classification has highlighted unique as well as uniform distributions more clearly than could be done for aggregate or "major" groups, at the 2-digit level. Only a few summary findings can be drawn, therefore, without aggravating the risk of aggregative statements.

1. Over the spectrum of urban and nonurban place sizes, food and beverage products as a whole have widest incidence. But individual food industries display sharply divergent locational pulls, some, as we have seen, concentrating in the largest cities, some in medium size or small cities, others in rural places. Transport, marketing, and process characteristics of individual industries would require examination to explain these locational contrasts.

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* For 135 additional industries covered in the 1964 manufacturing census, size of place distributions are not available for 10 percent or more of industry employment. No attempt was made to assign these industries to location categories.

2. Apparel, fabricated metal products, and wood products including furniture are widely distributed over all size urban places. Certain apparel industries have very high or high incidence in the largest cities; others have such incidence in the small and smallest cities outside metropolitan areas. Most metal fabricating industries have wide distribution in urban places, although a few have high incidence primarily in large cities. Wood product industries are more evenly spread in places of all sizes, including rural places.

3. Consumer product industries, largely encompassed in the two previous paragraphs, have wider location options than producer or intermediate good industries with respect to size of place. Each of the more basic industries is associated with a narrower range of city size groups, as follows.

4. Basic metals, machinery, and transport equipment have high incidence especially in cities of 10,000-99,999. Certain machinery industries have high medium size city incidence; others are more widely distributed than basic metals or transport equipment in cities of all size. Three important transport industries have high incidence in the smallest cities. Aluminum rolling is predominantly nonurban.

5. Basic chemicals are predominantly nonurban. They are slightly more drawn to nonurban localities in metropolitan than in nonmetropolitan areas, but also have nonmetropolitan significance.

6. Textile mills are oriented strongly to the small and smallest cities and to nonurban locales, in many instances outside metropolitan areas.

7. Industries strongly oriented to raw materials, such as pulp, paper, and paperboard, or stone, clay, and glass products, have high incidence in small and smallest cities as well as nonurban places outside metropolitan areas.

8. Frequent exceptions to these size of place patterns are observable in the detailed industry lists of Appendix B. The unclassified industries in list X are also instructive. Useful insights on urban advantages and disadvantages for specific manufactures can be gained by scrutiny of industrywise city size distributions, in conjunction with traditional industrial location analyses.

Comparative Observations. Four broad comparisons stand out from the above study of Indian and U.S. city size industrial patterns:

1. In the smallest cities, very similar types of industries are found, pulled particularly to resources by transport considerations. In small U.S. towns, wage differentials in the South have

contributed to attraction of textile manufactures on a major scale, a feature not evident in the study region except perhaps in incipient form.

2. Industries classed as ubiquitous in the U.S. are more numerous than in the three-state region of India, and more diversified in manufacturing characteristics.

3. The high incidence of machinery and metal manufactures in U.S. cities of 10,000-100,000 and 100,000-500,000 is a particular contrast to the present locational distribution of these industries in the study region. It can be inferred that U.S. cities of this size have achieved an adequate base of labor skills, specialized supplier industries, and communication links to attract such producer goods industries.

4. Prominent heavy industries, both in chemicals and basic metals, are often nonurban in character in the United States. Their incentive to be outside municipal areas from considerations of space, zoning, and tax obligations are probable explanatory factors. Evidently their physical infrastructure demands present volume or quality requirements that enable individual plants or complexes to achieve their own economies of scale. Industries of this kind would not appear central to an analysis of urban infrastructure requirements for developing economies.

In the above location analysis, a cross-classification of location by city size against the number and size distribution of plants within each industry has not been attempted, nor have differences in levels of technology between industries in India and the United States been incorporated in the analysis. Inclusion of these factors would no doubt contribute to the understanding of the observed city size distributions of industry.

Urban Infrastructural Requirements of Individual Industries

This section presents the field research strategy used to assess industrial infrastructure requirements; an illustration of the procedure with an analysis of one industry (sewing machines and parts); and summary tables of industry infrastructure coefficients for 75 industries. The intensity of infrastructure uses is analyzed in the next section.

Field Research Strategy

Selection of Industries. Choice of industries and sample firms for detailed field study was governed by two research objectives: (1) determination of prospective urban industries for the region, and (2) estimation of future infrastructure requirements of these industries. The conclusion had been reached in preliminary research conferences in India that

the main basis for infrastructure estimates would be direct in-plant interviews. This was necessary because industrial census data, apart from grouping many products, do not include details on floor space,* connected power load, power use factors, transport modes, industrial waste disposal, or proportion of skilled and unskilled workers. Granting the need for in-plant study, there was still the problem of devising valid procedures for projecting future requirements from present use patterns, taking into account not only industrial growth trends but also trends in scale of plant and technological as well as management improvement.

In selecting lines of manufacture for field study, four criteria were followed: (1) overall growth promise, based on strength of long term demand and on regional advantages and specialization; (2) inclusion of industries suited to cities of different size; (3) representation of varied physical and social infrastructure use levels; and (4) weight to industries serving agriculture, as suppliers or processers. The growth criterion tended to be foremost. For example, cotton textiles, which in many economies offer interesting opportunities for development in smaller towns and have distinctive infrastructure needs, were explored tentatively in field interviews but ultimately were given low priority because of the relative handicaps and secular decline of the existing textile industry in important centers of the region.

Guidance on emerging growth industries and the likely pattern of industrialization was sought from the following publications:

1. Government of India, Planning Commission, Perspective Planning Commission, Draft Fourth Plan: Material and Financial Balance 1964-65, 1970-71, and 1975-76, September 1966.

2. Government of India, Planning Commission, Fourth Five Year Plan: A Draft Outline, August 1966.

3. Government of India, Economic Survey 1966-67, presented to Indian Parliament in the Budget Session 1966-67.

4. National Council of Applied Economic Research, Industrial Programmes for the Fourth Plan: Punjab, Publications Division NCAER, July 1967.

5. Government of Uttar Pradesh, Directorate of Industries, Industrial Development Programmes for Uttar Pradesh during the Fourth Plan, Kanpur 1966.

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* Although the study does not cover costs of factory construction, as noted in Chapter II, data on floor space and storage space were required as a basis for estimating necessary site acreages and layout characteristics.

A large list of industries having locational attributes and infrastructure characteristics suited to cities in the region was drawn up with the aid of Annual Survey of Industries data* for the country as a whole and the three states. These indications were supplemented with judgments obtained at central, state, and local levels from experts, officials, industrialists, and professional institutes. The list of industries was reviewed and revised at each successive stage of field work to take into account new evidence on growth potential rather than presumptively limit the area of inquiry to predetermined categories.

An added reason for continual review of industry potential was that the field work was conducted during a period of extreme economic adversity and transition. Two years of monsoon failures had caused food scarcity on an emergency scale in nearby parts of the country and slack agricultural purchasing power in general, contributing to the industrial recession of 1966-67. Low utilization of industrial capacity, associated during the preceding years with raw material shortages, had been exacerbated in most manufacturing lines by the agricultural setback and by major reductions in the financing of development projects consequent to the outbreak of wars in 1962 and 1965. Growth targets earlier set up were under thorough reappraisal, while industrialists were adjusting to the significant effects of devaluation, credit squeeze, and import liberalization on profitability and expectations in different manufacturing lines. Neither governmental nor nongovernmental persons or agencies responsible for industrial growth could yet speak concretely on projects of industrial expansion or investment in new lines.

It was recognized, particularly during such a transitional period, that the project could not attempt to identify clearcut or definite industry mixes for different size cities. Instead, it was considered important to examine a representative range of industries with growth promise for such cities, in order to build up a matrix of industry infrastructure requirements that could serve as a tool of analysis for planners and as a basis for forming indicative mixes for the purpose of this project.

Choice of Sample Firms. Criteria for the selection of plants were (1) evidence of scale and technology meeting the conditions for competitive performance over the next period of industrial expansion, 10 years or so; and (2) management orientation to efficiency and to optimal use of infrastructure facilities. Selected modern plants in other cities and regions were surveyed for data on industries not adequately represented by efficient plants in the 18 cities.

A prerequisite to a selection of industrial plants was to have a "universe." Two lists were available to us for choice of a universe.

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* Government of India, Central Statistical Organization (Industrial Statistical Wing), Annual Survey of Industries 1963 in 10 Volumes, Manager of Publications, Delhi, 1966.

The first was a list of firms registered with the Industries Directorates of Uttar Pradesh and Punjab under state-sponsored assistance programs. This registration is discretionary in nature, but extends to all manufacturing firms irrespective of size or scale. The second was a list of firms registered under the Factories Act of 1948, which requires registration, for the enforcement of certain minimum welfare and safety standards, of every firm employing 10 or more persons with power, and 20 or more persons without power.* The list represents, to a fair degree of accuracy, the organized sector of manufacturing. For purposes of this project, we took the Factories Act list as the "universe." The total number of firms so registered in Uttar Pradesh and Punjab was 8,813 and 4,513 as of December 31, 1965, with an employment of 204,825 and 109,000, respectively.

This list was screened in two stages for making a final selection of firms for interview. In the first stage, we excluded industrial groups whose perspective demand outlook was not promising, and simultaneously took out manufacturing operations which were amenable only to large scale complexes, which were intrinsically resource tied, or where apparently, hand operations prevailed over the use of energy and modern equipment. In the second stage, assistance was sought of local interest groups and developmental agencies, whose intimate knowledge helped in identifying the efficient, consistently growing firms. Bias in favor of well-equipped, well-managed, medium scale firms was introduced. The technique of "local" participation in the process of sample selection proved purposeful to the research strategy.

In essence, the sampling method was purposive and controlled. The Research Plan had provided for 180 industry interviews. In the final analysis, 208 interviews were completed. Table 66 shows the size distribution of interviewed firms, by employment and production.

Questionnaire Design. The major elements in the questionnaire design are: infrastructural use levels, both economic and social; infrastructural bottlenecks affecting efficient plant working; prospective demand for the products manufactured, as estimated by the entrepreneur; new demands on infrastructure as the result of future expansion programs; main operational processes; reasons for present location; capital intensity; and production levels. The draft questionnaire was pretested in Ludhiana, resulting in substantial revisions in emphasis and sequence. Further revisions were made after testing the redrafted questionnaire in Amroha and Hapur. A copy of the final questionnaire is presented in Appendix B. Tests of internal consistency and current market knowledge were applied to isolate the invalid and unreliable information from the completed questionnaires.

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* Government of Uttar Pradesh, Labor Commissioner, List of Registered Factories, Kanpur, 1965, and Government of Punjab, Labor Commissioner, List of Registered Factories, Chandigarh, 1965. The Punjab list of registered factories includes Haryana.

Table 66

SIZE OF INTERVIEWED INDUSTRIAL FIRMS, ARRANGED BY EMPLOYMENT AND PRODUCTION, 1967

	Production (Rupees)							
Employment	Under 50,000	50,000-100,000	100,000-500,000	500,000-1,000,000	1,000,000-5,000,000	Over 5,000,000	n.a.	Total
Under 25	8	12	33	4	2		1	60
25-50	1	2	31	7	5	2		48
50-100		1	16	17	12	2		48
100-200				4	24	1		29
200-300					10	3	1	14
300-400					1	2		3
400-500					1	1		2
500 and over						3	1	4
Total	9	15	80	32	55	14	3	208

Source: Field survey.

Method of Data Collection and Analysis. Two visits were made to each industrial plant. The first was intended to familiarize the plant manager or proprietor with the project's purpose, significance, and tie with regional developmental problems, and to set a time for a detailed interview. A visit to the plant was also made to gain understanding of the management's role in planning effective use of machinery, equipment, and work place. A copy of the questionnaire was left with the respondent to help him assemble the statistical data from his records before the second interview. A number of questions pertaining to the background of the respondent, his interests in industrial development in general, and his line of production in particular preceded the main inquiry, which helped in establishing rapport and better understanding of the motivations of management. Besides the basic facts, interviewers' comments on the firm's operations were most meaningful for building up industrial infrastructure analyses.

As a basis for interfirm analysis, interview data on the economic characteristics and infrastructure use levels of each firm were tabulated by industry. For each industry, a coefficient sheet was prepared showing infrastructure use by each firm in relation to production, employment, and investment. Separately, data on urban facilities and needs were tabulated for all firms on citywise proformas.

Essentially, three steps were taken in analyzing the infrastructure requirements of each industry. First, interfirm comparisons were made to identify those firms evidencing efficiency and growth propensity. The judgment of industrial economists and industrial engineers who conducted the field interviews was an important element in this assessment, which took into account data on firms' growth and capacity utilization as well as observations on plant efficiency and product quality. Power use factors for the plants in a given industry were compared as a rough check on reported capacity utilization and as an indication of production efficency or of inadequate connected load.*

Idiosyncrasies in the coefficients of particular firms were examined to establish maximum consistency and comparability in the use of infrastructure within each industry, where not related to differences in productive efficiency. The steps involved in this analysis were complicated, as each firm like an individual has its own distinctiveness and any casual attempt failed to explain the differences in the existing use or consumption levels of infrastructural inputs. In fact it was difficult to find two firms of the same industrial category for which requirements per unit of output were the same. In short, the main factors reckoned with in the determination of infrastructural standards were:

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* The power use factor is defined as the ratio between annual kilowatt hour consumption and potential consumption, multiplied by 100. Potential consumption was taken as the product of connected load (in kilowatts), annual working days, number of shifts, and work hours per shift.

- Input variations on account of process differences
- Subcontracting of manufacturing operations
- Capital intensities, the problems of age and depreciated machineries
- Propensity of substitution of inputs
- Product and quality differences

Finally, the coefficients of firms under consideration were adjusted to their equivalents for 80 percent capacity utilization. This was judged to be a normal and appropriate level of utilization for determining infrastructure requirements. In this adjustment, "stock" infrastructure elements (floor space, storage space, and connected load) were kept at the same level, based on the assumption that a firm provides for these facilities at its maximum production capacity. The further assumption was made that the number of nonproduction employees would not change with increase to 80 percent capacity, but that production employees and "flow" infrastructure inputs (power consumption, water, and transport) would increase in direct proportion to production. The recomputed coefficients at 80 percent levels were taken as the basis for final determination of infrastructure needs for each industry.

An example of this evaluation process is given below, for the sewing machine industry.

Infrastructure Requirements for Sewing Machine and Parts Manufacture

The Product. Sewing machines are an important new manufacture in many industrializing countries, meeting demands for increased clothing production in households and garment-making shops and serving as a leader industry in development of metal-working technology and skills. Infrastructure requirements for this industry are examined here on the basis of field analysis of five firms which manufacture tailoring and domestic sewing machines and parts.

Demand. With the rise in family incomes, increasing use of readymade apparel, and gradual disintegration of the joint family system, demand for and production of sewing machines in India has increased steadily in recent years. According to the Monthly Statistics of the Production of Selected Industries of India,* the production of sewing machines increased 215 percent from 1954 to 1959, and 63 percent from 1959 to 1965. The rate of increase averages 8.5 percent per annum for the six year period. The

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* Government of India, Central Statistical Organization (Industrial Statistics Wing), Manager of Publications, Delhi, 1966.

increasing demand and general economic and social trends and prospects are favorable to continued growth of the sewing machine market. The Planning Commission* has estimated an annual production target of 1,800,000 sewing and knitting machines by 1975-76, compared to the present level of 433,000 machines. Further evidences of growth potential are available in the technoeconomic studies† made by the National Council of Applied Economic Research. An additional capacity for 80,000 sewing and knitting machines has been suggested for Punjab during the Fourth Plan. It has also estimated a demand of over 200,000 sewing machines in Uttar Pradesh by 1975-76.

Machinery, Equipment, and Process of Manufacture. The main machines used in the manufacture of sewing machines are cupola furnace for casting; turret, capstan and ordinary lathes, grinders, shapers, drilling, hobbing and milling machines, and hand and power presses for machining purposes; polishing machines, electroplating plant, heat treatment unit, and buffing machines for the finishing section; and tools, dies, drills, jigs, and fixtures appropriate for precision work and for assembly of complete machines. Almost all of these machines are manufactured in India.

The most important stage in the manufacture of sewing machines is machining, where the cast pieces are trimmed and cleaned, and other special steel parts are turned, shaped, drilled, and pressed to required specifications. The machining and finishing of internal and external dimensions require a high degree of precision and specialization to ensure smooth running and interchangeability of parts. Parts which are prone to early wear and tear are subjected to proper heat treatment for hardening. The external surfaces are painted and enamelled.

Raw Materials and Components. The principal raw materials required are (1) pig iron, grade I; (2) steel of various types, particularly free cutting, high speed, die alloy steel, mild steel rounds, and spring wire; (3) coal and hard coke, and (4) stores and supplies, which include oils and paints, electroplating salts, and circular sectional leather belting. Special steels are mainly imported. Assemblers of sewing machines require the following parts: (1) oscillating rock shaft, (2) face plate and arm side cover, (3) bobbins, (4) bobbin cases, (5) needle bar, (6) pressure foot, (7) link with stud, (8) square roller, (9) thread take up lever, (10) shuttle, and (11) shuttle carrier with spring. Difficulties were reported in availability of parts (4), (6), (9), and (10).

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* Planning Commission, Perspective Planning Division, Draft Fourth Plan - Material and Financial Balances, New Delhi, Septebmer 1966.

† National Council of Applied Economic Research, "Industrial Programmes for the Fourth Plan - Punjab," New Delhi, 1967, and "Techno-Economic Survey of Uttar Pradesh," New Delhi, 1965.

Structure of the Industry and of Interviewed Firms. Apart from self-contained large scale firms, medium and small firms are broadly of three types. First there are assemblers, which manufacture certain components and obtain others either from specialized parts manufacturers, large firms, or imports. Among the firms interviewed (Table 67), firms III-A, III-B, and V-C fall in this category. V-C is also a subcontract manufacturer for stands and pedestals, substantially raising the proportion of casting work compared to the normal proportion between machining and casting in firms in this category. As we will see, this fact affects the coefficients of this firm appreciably. Second, there are firms that specialize in the manufacture of specific parts. III-D is a typical example of this group, manufacturing shuttles, a very complicated and vital machine component. Thirdly, there are firms which undertake mainly casting jobs for assemblers on contract; V-E represents this category.

The three firms engaged in the manufacture and assembly of complete sewing machines are all well organized, with standing, and considerable business and technical experience. Although registered as small units, they exhibit the characteristics of medium scale business. The other two firms, although operating on a factory basis, are relatively smaller in size and reflect characteristics of typical small units in the region.

Growth Centers. The main production centers of the industry in the region are Jullundur, Ludhiana, Batala, and Bassi Pathan in Punjab, Ambala in Haryana, and Hapur in Uttar Pradesh. Out of a total of 225 companies manufacturing sewing machines and parts in the country in 1966, 163 or 72 percent were located in Punjab. The share of Uttar Pradesh was 6 percent. This concentration of sewing machine industry in the region and particularly in Punjab may be attributed largely to the availability of skill, and the mechanical disposition and enterprising spirit of the people. The availability of skill will influence the future locations of the industry, and since the field region has an abundant supply of this, it may continue to sustain its position in manufacturing sewing machines in the country.

Economic Characteristics and Infrastructure Requirements. Table 67 indicates the basic characteristics of the interviewed firms. It is observed from the table that excepting III-D which was established in 1957, the remaining firms came into being in the early 1950s. This was the period when industrialization in the country had started to gain momentum, and the sewing machine industry along with other light engineering industries in the field region, particularly in the Punjab, had started to take root.

The scale of employment and production for firms engaged in complete sewing machine manufacture is much higher than for those which make a single part or component or work on a subcontract basis.

The growth of the interviewed firms in production was consistent between 1961-66. Those in the first category increased their production by

Table 67

SEWING MACHINES - ECONOMIC CHARACTERISTICS

Firm	Year of Establishment	Product Manufactured	Employment Size 1966-67 (no.)	Production 1961-62 (Rs. 000)	Production 1966-67 (Rs. 000)	Production Increase 1961-62 1966-67 (%)	Production Capacity 1966-67 (Rs. 000)	Percent of Production to Capacity 1966-67 (%)
III-A	1953	Sewing machines	195	1,784	2,345	31.7	n.a.	n.a.
III-B	1950	Sewing machines	160	1,500	1,900	26.7	2,280	83.3
V-C	1950	Sewing machines	179	1,000	1,390	39.0	2,000	69.5
III-D	1957	Shuttles	40	140	200	42.9	n.a.	n.a.
V-E	1954	Cast pieces (bodies & stands)	35	153	292	90.8	292	100.0

n.a. = not available.

Source: Field survey.

annual rates of 5.2 to 7.8 percent. Increase in production for the two firms making specific parts or components was higher than for the first category. This perhaps is an indication that the ancillary sector manufacturing sewing machine parts both for the main assemblers and for replacement sustains itself very well in the context of the prevailing structure of the industry.

Information on utilization of production capacity is available for three out of five interviewed firms. V-E reported full utilization of the plant's capacity, III-B was functioning at 83 percent of capacity, and V-C at 70 percent. Considering the recessionary trends in the economy at the time of field investigation, the reported high capacity use reveals an inherent strength of the product in the overall industrial structure of the economy.

As explained in an earlier section, coefficients have been adjusted to 80 percent capacity utilization for determination of infrastructure needs. The main assumptions here are (1) that stock facilities (floor and storage space and connected load) and the number of nonproduction employees will remain the same if the firm raises its production level to 80 percent capacity, and (2) that flow inputs (power consumption, transport, and water) as well as production employees will increase in the same proportion as production. Capacity utilization of 80 percent would raise the production of firm V-C from Rs. 1,390,000 to Rs. 1,600,000--i.e., by a factor of 1.15. Stock coefficients per unit of production are reduced by this factor (dividing by 1.15), flow coefficients are unchanged, while coefficients per employee change in accord with the assumed increase in production employees.

Production per Employee. There are three distinct production levels related to the products manufactured. In the first category, annual production per employee for III-A and III-B are in a close range of Rs. 11,800 and Rs. 12,000. The production per employee is considerably lower for V-C; this is explained by the greater share of casting operations (stands and pedestals) in the total production, which tends to lower the value of output per employee. For this reason, it is not considered an appropriate coefficient for the sewing machine industry. The coefficients of production per employee for III-D and V-E are substantially lower, as expected.

Floor Space. Use of floor space and its coefficients with respect to the interviewed companies are presented in Table 68. Table 68 shows that the total floor space for companies making complete sewing machines with production levels ranging from Rs. 1,598,500 to Rs. 2,345,000 varies from 43,500 to 54,900 square feet. V-E records a much higher floor space (14,400 square feet) in relation to its production level, resulting in the highest floor space use per employee and per Rs. 1,000 of production. This is explained by the fact that V-E is exclusively engaged in foundry work in which the process makes greater demands on floor space.

Table 68

SEWING MACHINES - FLOOR SPACE

Firm	Total Floor Space (sq ft)	Floor Space/ Employee (sq ft)	Floor Space/ Rs. 1,000 Production (sq ft)
III-A	45,000	230	19.2
III-B	43,500	272	22.0
V-C	54,900	270	34.3
III-D	2,880	72	14.4
V-E	14,400	410	49.3

Source: Field survey.

The other extreme is III-D (making shuttles) which records lowest floor space per employee and per Rs. 1000 production. This situation is explained partly by the location of the firm in the Industrial Estate which offers limited floor space for operation of the business, much less for expansion, and partly by the nature of the process of manufacture itself. The process requires forging; machining the forged rough blanks on a number of lathes fitted with jigs, fixtures and tools; and buffing. The space requirement would have been still less if a few stages in the total process could have been combined by means of imaginative jigs and fixtures or by developing a machine which could do multiple processes at a time. Likewise, the space requirement would be lower in the foundry shop, if a machine were used for making sand molds in place of manual labor. It is here that the technological aspect comes into play and influences the infrastructural requirements. We suggest about 250 square feet per employee for firms making complete sewing machines, the average of III-A and III-B. For Rs. 1,000 production, the floor space requirement could be 21 square feet.

Power. The main requirement of power is for machining and electroplating. Coefficients of power use are presented in Table 69.

In terms of power use, there is appreciable degree of divergence between the three firms of the first category. III-B has a low connected load of .036 kw, as against .064 kw for III-A and .094 kw for V-C, all expressed in Rs. 1,000 production. Per employee connected loads for V-C and III-A are in close range. There is some ambiguity with respect to connected load and power consumption for III-B, in the sense that the firm was either having a fan manufacturing unit within the main firm or had such a unit as an adjunct, making some sort of demand on power consumption. No satisfactory explanation was available during the interview. In view of the uncertainty of explanation for III-B, we have suggested III-A data on power, as valid for sewing machine industry, since the III-A data also show a reasonable power-use factor. Since V-C combines greater degree of casting with machining tending to lower power use, power coefficients of this firm may not be treated as representative. The connected load per Rs. 1,000 production and per employee works out to 0.064 kw and .766 kw; the consumption coefficients are 76 kwh and 909 kwh respectively.

Transport. Of the three firms making complete machines, only two have reported information on transportation. For V-C, the tonnage per Rs. 1,000 production is 2.30 tons, compared to 1.60 tons for III-B. The field notes attribute the difference in tonnage to the higher quantum of local purchases of bulky raw materials (pig iron and coke) by III-B as compared to V-C, which gets all pig iron and coke in wagon loads directly from the source. This also explains higher rail tonnage for V-C as compared to III-B. Secondly, the lower production value for V-C has tended to inflate the tonnage requirement. In view of this, coefficients of III-B have been suggested as valid for this industry.

Table 69

SEWING MACHINES - POWER

Firm	Connected Load/Employee (kw)	Connected Load (kw)/Rs. 1,000 of Production	Consumption (kwh)/Employee	Consumption (kwh)/Rs. 1,000 of Production	Power Use Factor*
III-A	0.769	0.064	923	76	40.0
III-B	0.425	0.036	524	44	51.5
V-C	0.739	0.094	255	32	12.4
III-D	0.275	0.055	n.a.	n.a.	n.a.
V-E	0.256	0.031	319	41	51.6

* See definition, page 204.
n.a. = not available.
Source: Field Survey.

V-E records 0.07 tons of road transportation per Rs. 1,000 of production and no rail transportation since the firm makes local purchases of the raw materials (coke and pig iron), and uses road transport for sending cast bodies. III-D making sewing machine shuttles records 0.01 tons rail transportation per Rs. 1,000 of production and similar tonnage for road. The raw material in this case also is locally purchased. The finished products, however, being amenable to compact packing in wooden cases involving little risk of breakage and meant for distant places--Madras, Calcutta, Bombay, Ahmedabad--are sent by rail.

Water. Out of the three units making complete machines, information on water use is available for two firms whose consumption levels differ widely. V-C records a high level of water consumption compared to III-A. This is explained by the fact that the manufacture of stands and pedestals by V-C constitute a sizable portion of total production and have to be rubbed and washed time and again, before painting. As such, V-C shows higher water use. The other two firms have limited use of water in manufacturing operations. We suggest III-A coefficients on water use, 448 gallons per Rs. 1,000 production and 18 gallons per day per employee, as valid requirements.

Storage Space. The main raw materials used in the manufacture of sewing machines are coal, hard coke, and pig iron. These are generally stored in the open. The covered storage space is required only for semi-finished and finished goods in volumes which depend on the firm's efficiency in organizing sales.

Out of five firms, only two have reported information on this facility: one making complete sewing machines, and the other engaged in casting machine bodies. The latter is ancillary to firms making complete machines. Field notes suggest that the storage space data for the former are not valid because of inefficient use of space. Even though the latter is a subsidiary firm, we suggest its coefficient of 0.2 square feet per Rs. 1,000 production as the covered storage space requirement for the sewing machine industry

Effluent Disposal. Items of waste requiring disposal are slag (from the foundry), iron scrap (from the machine shop), and water (from the electroplating section). The slag is generally used to fill the depressions for levelling factory grounds or is thrown out. Iron scrap is sold to local dealers who collect the same from factory to factory and dispatch it to port towns for export. Water used for rubbing and washing the stands and for electroplating certain components flows out in the drains without any treatment. Information pertaining to quantity requiring disposal is very scanty, and hence no quantitative estimates on the industrial wastes are possible.

Skill Requirements. In the section on growth centers, it was observed that the industry is skill oriented, requiring, in particular, skills in foundry and machine shop trades. Industry dependence on the support of servicing units such as heat-treatment, electroplating, and enamelling is also considerable.

The fact that the industry is skill oriented is borne out by the larger proportion of workers who are in higher pay ranges. Persons drawing above Rs. 100 per month may be considered as belonging to the category of skilled personnel. This is in conformity with the prevailing wage structure in the field region. Measured by this standard, 62 percent of the total employees (401 out of 644) reported by the interviewed companies fall in the skilled category. Another fact that confirms this is the higher content of labor going into the manufacture of components requiring exclusively machining jobs--III-D. In this case, out of a total of 40 employees, only five draw less than Rs. 100 per month, 15 fall in the pay range of Rs. 100-200 per month, and the remaining 20 are reported to be drawing over Rs. 200 per month. Judged by the same standards--wages per month--88 percent of the total workers in III-D are in the category of skilled employees.

In contrast to this, V-E engaged in foundry shop records only 9 percent of the total workers (3 out of 35) as skilled.

From this discussion two things stand out:

1. The industry is skill oriented.

2. The percentage of skilled persons required in the machine shop is much higher than the percentage required in the foundry shop.

Conclusion. The above discussion reveals that, skills being the foundation, the main infrastructure requirements of this industry are: (1) rail and road transport, for bringing raw material and for carrying finished goods to the consuming points, and (2) power. Effective sales organization makes a positive contribution to the successful working of the firms in this line. The distribution costs, although not dealt with in this role, are as high as 20 percent of the total cost of the machine.

The selected coefficients of infrastructure requirements with respect to the complete sewing machine as well as for the casting of sewing machine parts are included in the Coefficient Summary Tables that follow.

The Coefficient Summary Tables

Through analysis of plant interview data on the above lines, infrastructure requirements per unit of production and per employee were established for each industry surveyed. In order to relate infrastructure inputs to net industrial output, these coefficients were converted to value

added equivalents. This was done by dividing the coefficients per unit of production by the percentage of value added to gross production for the corresponding industry in the Annual Survey of Industries, 1963. Tables 70 and 71 present the coefficients per unit of value added and per employee, for 75 industries.

As indicated earlier, the coefficients are forward looking. They represent plants that are somewhat above the average plant in the 18 cities in technology and management efficiency. The adjustment of inputs to 80 percent capacity operation has removed the effects of slack industrial capacity, which would otherwise have led to systematic overestimation of requirements. Moreover, in identifying the appropriate use-level for each infrastructure service, an effort has been made to reflect best current practice and management capability among the plants visited.

Tables 70 and 71 are used in Chapter V to develop bills of infrastructure requirements for industries selected as appropriate for cities of different size, as a basis for incremental cost estimation. In addition, the tables are designed to be of use in other developing cities and countries in building order of magnitude estimates of the infrastructure required in support of various sets of industries. Because of the wide variety of products, product quality, and levels of technology that exist in most industries, and the relatively limited sample of firms interviewed, the coefficients should be looked on as indicative of the general range of requirements for different types of industry, to be supplemented or compared with other data on individual plant requirements. However, the patterns of infrastructure use-intensity described in the next section suggest considerable internal consistency in the coefficients, confirming their usefulness for planning urban infrastructure requirements and for further comparative analysis.

Intensity of Infrastructure Uses by Different Industry Groups

Infrastructure is an important variable influencing industry locations. That many governments in developing countries are now investing in "infrastructure"--in the form of developed industrial areas, industrial estates, or basic urban facilities--as a means of promoting and spatially organizing industrial activities speaks for its pre-eminence in recent times. The governments are concerned, more than ever, with a realistic assessment of infrastructural requirements related to potential patterns of industrialization, so as to make best use of scarce capital resources.*

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* An excellent discussion of the interrelation between industry and infrastructure is provided in B. V. Cholanovitch, "Dependence of Type of Infrastructure upon Type of Industrialization," published in Regional Economic Planning: Techniques of Analysis for Less Developed Areas, Walter Isard and John Cumberland (Eds.) for Organization for European Economic Cooperation, Paris, 1961.

Table 70

ECONOMIC CHARACTERISTICS AND INFRASTRUCTURE REQUIREMENTS PER RS. 1,000 VALUE ADDED FOR SELECTED INDIAN INDUSTRIES 1967

Industry Code	Industry Title	Fixed Investment (Rs.)	Production (Rs.)	Employees (No.)	Floor Space (sq ft)	Storage Space (sq ft)	Power: Connected Load (kw)	Power: Consumption (kwh)	Water (gal)	Transport: Road (tons)	Transport: Rail (tons)	Transport: Total (tons)
203	Canning & preserving of fruits & vegetables											
	a. Dehydrated	831	4,695	0.554	22	22	0.080	384	28,169	5.32	0.28	6.10
	b Canning & preserving	519	4,695	0.488	53	100	0.075	239	27,831	8.03	2.16	10.19
205-1	Flour mills	1,547	18,868	0.113	79	8	0.434	2,181	17,981	16.23*	32.45	48.68*
205-2	Rice Mills	1,098	20,408	0.163	395	93	0.531	790	102+	15.51*	n.a	15.51*
206	Bakery products	677	3,472	0.204	54	5	0.093	83	1,521	0.56*	2.43	2.99*
209-2	Edible oils											
	a Oil expellers‡	795	22,727	0.250	205	164	1.432	1.282	9.136	19.55*	11.14	30.69*
	b Solvent extraction‡	3,373	19,608	0.333	335	318	1.353	1,020	18,059	22.55	30.00	52.55
209-7	Starch‡	840	5,155	0.144	121	11	0.711	925	17,708	1.86*	10.62	12.48*
209-8	Cold storage‡	11,142	6,173	0.310	2,315	309	9.203	10,333	1,567	30.20	22.80	53.00
231-1	Cotton textiles (power looms)‡	362	3,817	0.298	126	2	0.367	298	445	3.28*	2.37	5.65*
231-7	Textile finishing & processing											
	a. Single process	1,876	3,984	1.076	247	13	1.928	1,406	40,717	8.29	5.62	13.91
	b Composite process‡	2,514	3,984	0.478	233	67	1.434	976	33,199	0.84	3.23	4.07
232	Knitting mills (woolen hosiery)	1,626	4,405	0.170	37	13	0.022	45	101+	3.78*	2.73	6.51*
239-5	Artificial leather & oil cloth	1,650	5,000	0.420	12	12	0.366	572	43,452	84.40	n.a	84.40*
260-2	Metal furniture & fixtures	294	3,236	0.230	15	3	0.060	77	175	0.97	0.23	1.20
271-4	Paper board and straw board	2,268	3,571	0.564	128	400	0.418	523	272,143	3.90*	3.71	7.61*
271-5	Paper for packaging	1,022	5,435	0.636	34	15	0.401	589	380	0.43	1.36	1.79*
291	Tanneries & leather finishing	418	7,246	0.439	304	212	0.217	340	1,642	2.46	0.29	2.75
300-3	Rubber footwear	237	2,457	0.143	14	3	0.125	211	28,349	2.48	0.37	2.85
300-4	Other rubber products (rubber beltings)	158	5,076	0.188	35	2	0.244	254	457	3.00	1.37	4.37
311-2.1	Inorganic chemicals	85	3,559	0.064	27	12	0.030	51	580	2.46	18.83	21.29
313	Paints, varnishes & lacquers	486	3,484	0.111	29	4	0.181	66	192	0.40*	1.29	1.69*
319-2	Insecticides, fungicides, & weedicides	619	4,950	0.150	18	9	0.144	614	79	3.71*	1.24	4.95*
319-5	Drugs & pharmaceuticals	582	5,291	0.471	80	18	0.085	124	1,566	0.29	0.75	1.04
339-2	Hume pipes & other cement & concrete products	1,494	2,833	0.235	23	n.a.	0.085	100	4,788	55.69*	12.01	67.70*
339-6	Abrasives	2,024	2,681	0.110	85	32	0.350	134	175	0.32	0.75	1.07
341-1	Iron and steel (metal)											
	a Re-rolling	538	3,953	0.119	33	10	0.498	870	9,960	4.03*	7.08	11.11*
	b Re-rolling with electric furnace	1,346	3,236	0.125	58	8	0.793	1,456	59,061	1.94*	0.97	2.91*
341-4	Iron & steel structurals (light)	399	3,145	0.063	22	6	0.167	70	366	0.12	0.42	0.54
341-5	Iron & steel pipes											
	a Conduit pipes	912	4,464	0.571	150	57	0.401	213	431	2.09	3.33	5.42
	b Cast iron pipes	357	4,464	0.777	154	31	0.107	108	1,488	3.71	10.40	14.11
350-1	Metal containers & steel trunks											
	a Metal containers	164	4,444	0.160	28	1	0.093	135	98+	0.39*	1.56	1.95*
	b Utensils	876	4,444	0.441	112	47	0.413	524	2,013	1.28	1.94	3.22
350-3	Bolts, nuts, nails, screws, etc	777	3,984	0.215	57	12	0.137	228	3,112	1.83*	4.63	6.46*
350-9	Hurricane lanterns & torches	77	3,165	0.304	24	3	0.079	99	184+	0.26	0.97	1.23
350-10	Hand tools & small tools											
	a Hand tools	188	2,320	0.213	39	16	0.218	44	128+	0.74*	1.53	2.27*
	b Small & cutting tools	269	2,320	0.253	16	4	0.218	140	113	n.a	n.a.	n.a
350-12	Sanitary & plumbing fixtures & fittings of metal	404	3,704	0.440	25	2	0.144	165	1,981	0.11	0.11	0.22
350-13	Weights	94	3,484	0.274	30	3	0.066	110	1,038	3.62*	5.05	8.67*

Table 70 (concluded)

Industry Code	Industry Title	Fixed Investment (Rs.)	Production (Rs.)	Employees (No.)	Floor Space (sq ft)	Storage Space (sq ft)	Power: Connected Load (kw)	Power: Consumption (kwh)	Water (gal)	Transport: Road (tons)	Transport: Rail (tons)	Transport: Total (tons)
360-3	Internal combustion engines	716	2,451	0.272	83	10	0 103	100	3,836	0 29*	1 70	1 99*
360-4.4	Sugar machinery	929	2,382	0.148	38	14	0 121	203	2,416	2 02	4 76	6 78
360-5 2	Conveying equipment	606	3,205	0.420	50	11	0 288	176	250+	0.95	1.07	2.02
360-5 11	Power driven pumps	948	3,185	0.226	41	6	0 096	85	3,981	1 10	1 59	2.69
360-5 12	Air & gas compressors & vacuum pumps	448	3,597	0.036	50	10	0 111	173	22+	2.09	0 18	2.27
360-7	Machine tools											
	a General purpose	566	2,632	0.376	66	47	0 260	178	705	2.40	2.79	5 19
	b Precision & special	1,217	2,433	0.097	12	4	0 171	75	58	0.44	0.34	0.78
360-8.2	Agricultural implements											
	a Harrows, cultivators & plows	411	3,953	0.186	29	15	0 071	102	160	4.54	1.25	5.79
	b Wheat threshers	585	3,953	0.352	57	10	0 150	138	69	3 42	0 33	3.75
	c Dusters & sprayers	162	3,953	0 490	17	n.a	0.130	57	527	n.a	n a.	n.a
	d. Hand pumps	162	3,953	0.530	122	23	0.143	256	316†	2.40	5.90	8.30
	e Crushers & expellers	1,111	3,953	0.751	164	18	0.198	254	1,415	3.35	2 82	6.17
	f Chaff cutters & spare parts	190	5,208	0.401	72	38	0 208	198	9,010	3 07*	9.17	12.24*
	g Chaff cutter blades	772	2,915	0.120	42	4	0.242	219	254	1.34	1.31	2 65
360-11.5	Sewing & knitting machines											
	a Complete sewing machines	353	2,890	0.242	61	1	0.185	220	1,295	3.27*	1.36	4 63*
	b Casting of machine parts	143	3,484	0.348	172	1	0 108	143	359	5.23	0	5 23*
360-11 6	Other equipment (nonelectric household)	114	4,000	0.560	63	23	0.132	227	560	0 88	6 72	7 60
370-1	Electrical equipment	387	3,704	0.370	30	8	0.093	118	3,730	1 07	0.11	1 18
370-1.1	Equipment for generation, transmission, & distribution of electricity											
	a Switchgears	156	3,704	0.441	70	9	0.115	108	619	2 05	0.96	3 01
	b Transformers	578	3,704	0 370	20	6	0 122	81	456	1.40	0 20	1.60
	c Electric carbon	1,481	3,704	0.622	133	78	2 960	1,748	4,444	0	0 75	0.75
370-1 2	Electrical motors	743	2,653	0 281	14	2	0 086	85	170†	0.05*	0.08	0 13*
370-1.4	Electrical lamps	341	2,967	0.451	15	2	0.058	85	3,136	0.09	0 09	0 18*
370-1.6	Electrical cables & wires	527	4,425	0 049	9	2	0 408	591	140	0.35	n a	0 35*
370-1 10	Storage batteries	191	2,625	0.801	41	18	0 721	1,172	480†	3.07	n a	3 07*
370-2.3 and 2 4	Wireless communication apparatus & equipment	750	3,636	0.247	16	5	0.084	67	149†	0.91	0 18	0 09
385	Bicycles	n a.	4,292	0 132	27	n.a	0 148	57	5,103	3 22*	0 43	3 65*
389	Transport equipment											
	a Auto parts	446	4,292	0 600	85	51	0 275	277	3,524	0.90*	2 10	3.00*
	b Bushes	326	4,292	0.124	15	2	0.086	155	451	0.78	0	0 78
391-1	Surgical instruments	260	3,333	0.293	21	4	0.170	227	250	1.53	0 17	1.70
391-3	Scientific instruments, etc.											
	a Scientific instruments	342	1,931	0 230	43	5	0 102	68	262	0.06*	0 15	0 21*
	b Optics	117	1,931	0 C97	5	0	0.012	17	58+	0	0 02	0 02
391-4	Mathematical, surveying, & drawing instruments	104	1,764	0 515	33	6	0 053	47	309†	0.04*	0 01	0.05*
399-7	Plastic moulded goods	1,412	3,891	0 191	28	11	0.272	491	5,148	0.59	0 11	0.70
399-11	Games & sports goods	260	3,937	0.280	197	48	0 248	191	1,095	2.56*	0	2 56*
512	Gas manufacture	2,122	2,538	0 206	23	6	1.187	2,030	5,076	16 50	4 30	20.80

n.a. = not available

* Partial information only
\+ Estimated
‡ Three shift operation
§ Two shift operation

Source: Field survey.

Table 71

ECONOMIC CHARACTERISTICS AND INFRASTRUCTURE REQUIREMENTS PER EMPLOYEE FOR SELECTED INDIAN INDUSTRIES, 1967

Industry Code	Industry Title	Fixed Investment (Rs)	Production (Rs)	Value Added (Rs)	Floor Space (sq ft)	Power: Connected load (kw)	Power: Consumption (kwh)	Water (gal/day)	Transport (tons)
203	Canning & preserving of fruits & vegetables								
	a Dehydrated	1,504	8,496	1,810	39	0 14	695	425	11
	b Canning & preserving	1,060	9,594	2,044	108	0 15	488	190	21
205-1	Flour mills	13,675	167,582	8,882	698	3 81	19,370	528	432*
205-2	Rice mills	6,534	121,453	5,951	2,351	3 16	4,700	2†	92*
206	Bakery products	3,310	16,970	4,887	263	0 45	407	25	15*
209-2	Edible oils								
	a Oil expellers‡	3,185	91,837	4,041	828	5 94	5 184	181	124*
	b Solvent extraction‡	10,006	58 155	2,966	993	3 99	3,024	179	156
209-7	Starch‡	5,868	36,059	6,995	840	4 95	6,469	378	87*
209-8	Cold storage‡	37,143	20,571	3,333	7,714	30.69	34 436	25	177
231-1	Cotton textiles (power looms)‡	1 215	12,737	3 337	423	1.23	1,001	5	19*
231-7	Textile finishing & processing								
	a Single process	1,744	3,700	929	230	1.79	1,307	126	13
	b Composite process‡	5,221	8,275	2,077	483	2,91	2,029	230	8
232	Knitting mills (woolen hosiery)	9 546	25,870	5,872	218	0 13	267	2†	38*
239-5	Artificial leather & oil cloth	3 926	11,892	2 378	28	0 87	1,359	354	201*
260-2	Metal furniture & fixtures	1,351	14,865	4,593	68	0 30	352	3	6
271-4	Paper board & straw board	4,018	6 333	1,773	227	0 74	927	1,607	13*
271-5	Paper for packaging	1,607	8,571	1,597	53	0.64	928	2	3*
291	Tanneries & leather finishing	952	16 500	2,277	693	0 49	775	93	6
300-3	Rubber footwear	1,650	17,109	6,963	96	0 87	1,472	658	20
300-4	Other rubber products (rubber beltings)	847	27,121	5,343	185	1 30	1,356	8	23
311-2 1	Inorganic chemicals	1,395	56,026	15,743	419	0.48	805	30	335
313	Paints, varnishes & lacquers	4,309	30,868	8 859	256	1.61	586	5	15*
319-2	Insecticides, fungicides & weedicides	4,706	37,500	7,575	138	1 10	4,139	2	37*
319-5	Drugs & pharmaceuticals	1,240	11,274	2,131	170	0 18	264	13	2
339-2	Hume pipes & other cement & concrete products	6,383	12,102	4,272	97	0 36	426	68	289*
339-6	Abrasives	17,500	23,178	8,645	730	3 07	1,157	5	9
341-1	Iron and steel (metal)								
	a Re-rolling	4,578	33,660	8,516	278	4 24	7,405	247	95*
	b Re-rolling with electric furnace	10,730	25,777	7,965	464	6 30	11,595	1,900	23*
341-4	Iron & steel structurals (light)	6,368	50,016	15,905	355	2 63	1,121	131	9
341-5	Iron & steel pipes								
	a Conduit pipes	1,597	7,816	1,751	262	0.71	373	3	9
	b Cast iron pipes	459	5,737	1,285	198	0.14	139	6	18
350-1	Metal containers & steel trunks								
	a Metal containers	1,032	27,966	6,292	176	0 59	850	2*	12*
	b Utensils	1,980	10,070	2,266	255	0 94	1,030	15	7
350-3	Bolts, nuts, nails, screws, etc	3,630	18,614	4,672	264	0.64	1,065	28	30*
350-9	Hurricane lanterns & torches	255	10,457	3,304	78	0.26	326	2*	4
350-10	Hand tools & small tools								
	a Hand tools	878	10,812	4,660	182	1 01	205	2*	11*
	b Small & cutting tools	1,067	9,209	3,969	62	0 87	537	2	n a
350-12	Sanitary & plumbing fixtures & fittings of metal	941	8,595	2,321	58	0 34	384	15	1
350-13	Weights	342	12,700	3,645	109	0.24	402	13	32*

Table 71 (concluded)

Industry Code	Industry Title	Fixed Investment (Rs)	Production (Rs)	Value Added (Rs)	Floor Space (sq ft)	Power: Connected load (kw)	Power: Consumption (kwh)	Water (gal/day)	Transport (tons)
360-3	Internal combustion engines	2,632	9 011	3,676	304	0 38	371	17	7*
360-1 1	Sugar machinery	6,249	16,027	6 728	253	0 82	1,366	366	46
360-5 2	Conveying equipment	1,152	7,680	2,396	120	0 69	422	2+	5
360-5 11	Power driven pumps	4,190	14,021	4 403	183	0 42	376	58	12
360-5 12	Air & gas compressors & vacuum pumps	1,250	10,031	2,789	141	0 31	481	2+	6
360-7	Machine tools								
	a General purpose	1,503	7,000	2,660	175	0 70	173	6	11
	b Precision & special	12,500	24,979	10,266	125	1 75	770	2	8
360-8 2	Agricultural implements								
	a Harrows cultivators, & plows	2,199	21,145	5,350	152	0 38	543	3	31
	b Wheat threshers	1,671	11,288	2 856	162	0 43	394	4	11
	c Dusters & sprayers	n a	8,036	2,033	36	0 27	115	1	n a
	d Hand pumps	305	7,437	1,882	229	0 27	481	2†	16
	e Crushers & expellers	1,478	5,267	1,333	219	0.27	338	7	8
	f Chaff cutters & spare parts	474	13,005	2,497	180	0 52	491	83	31*
	g Chaff cutter blades	6,450	24,355	8,354	353	2 02	1,828	7	22
360-11 5	Sewing & knitting machines								
	a Complete sewing machines	1,459	11,950	4,135	251	0 77	909	18	19*
	b Casting of machine parts	342	8,343	2,394	410	0 26	342	3	13*
360-11 6	Other equipment (nonelectric household)	207	7,213	1,803	114	0 24	409	3	14
370-1	Electrical equipment	1,054	10,092	2,725	82	0 24	323	33	3
370-1 1	Equipment for generation, transmission & distribution of electricity								
	a Switchgears	352	8,371	2,260	157	0.26	244	5	7
	b Transformers	1,562	10,014	2,704	54	0 33	218	4	4
	c Electric carbon	2,381	5,952	1,607	214	4.76	2 809	24	1
370-1 2	Electrical motors	2,641	9,387	3,539	51	0 31	301	2+	negl.*
370-1 4	Electrical lamps	754	6 567	2,213	32	0 13	188	23	negl.*
370-1 6	Electrical cables & wires	10,940	92,059	20,805	181	8 50	12,288	10	7*
370-1 10	Storage batteries	239	3,274	1,247	51	0.90	1,462	2+	4*
370-2 3 and 2 4	Wireless communication apparatus & equipment	3,020	14,637	4,025	64	0 34	269	2+	4
385	Bicycles	n a	32,550	7,584	220	1 12	435	129	28*
389	Transport equipment								
	a Auto parts	717	6,898	1,607	136	0 41	444	19	5*
	b Bushes	2,576	33,952	7,911	116	0.68	1,324	12	6
391-1	Surgical instruments	893	11,429	3,429	71	0 59	779	3	6
391-3	Scientific instruments, etc								
	a Scientific instruments	1,476	8,328	1,311	181	0 44	294	4	1*
	b Optics	1,211	20,058	10,930	48	0 13	173	2†	negl.
391-4	Mathematical, surveying & drawing instruments	203	3,429	1,944	65	0 10	91	2†	negl.*
399-7	Plastic moulded goods	7,399	20,384	5,239	148	1 43	2,571	99	4
399-11	Games & sports goods	925	13,993	3,554	701	0.88	681	13	9
512	Gas manufacture	10,363	12,402	4,886	113	5 80	9,917	83	102

n.a = not available, negl = negligible

* Partial information only
\+ Estimated
‡ Three shift operation
§ Two shift operation

Source: Field survey.

Such an assessment is considered necessary because some industries are high users of physical infrastructure inputs while others place greater demands on social infrastructure. Each condition warrants a different pattern of infrastructure planning and a different order of investment magnitude.* It is in this context that we discuss use-intensities of infrastructural facilities of different industries. We have made use of infrastructure coefficients as given in Table 70 and 71, for delineating high infrastructure user industries from medium and low users. Attempt has been made to explain the clusters of industries of different use levels in relation to the main manufacturing processes and labor or capital intensive nature of the industries.

Floor Space

Floor space here refers to covered space used for manufacturing, packing, storing, and other uses ancillary to production. Table 72 arranged by employee and Rs. 1,000 value added shows clusters of industries by the level of space use.

It is observed from the table that floor space per employee and Rs. 1,000 value added is very high (over 350 and 100 square feet, respectively) for the processing group of industries which includes leather tanning and finishing, edible oils by expellers and solvent extraction method, cold storage, rice mills, cotton textile power looms, textile processing and finishing, and starch.

Casting of sewing machine parts like pedestals and stands, and manufacture of games and sport goods are also very high space users. Other industries which are space extensive on an employee basis are flour mills, abrasives, rolling with electric furnace, chaff cutter blades, inorganic chemicals, and light structurals. As is noted, industries here are either processing or mixing types, or those requiring heavy furnaces making the operations relatively hazardous. Steel rolling with electric furnace and chaff cutter blades are of the latter type, necessitating larger floor space per employee. Since the value added by manufacture of these industries is high, floor space requirements in terms of value added are pulled down.

When we move to the next category, high users of space--where the floor space varies between 175-349 square feet per employee--we find that among industries which have casting as a principal manufacturing operation, there is a relatively greater proportion of grinding and machining work, compared to the casting of sewing machine parts. Instances are hand pumps, crushers and expellers, chaff cutters and parts, internal

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* John F. Dyckman, "Capital Requirements for Urban Social Overheads" in Science, Technology, and Development, Vol. VII, Social Problems of Development and Urbanization, U.S. papers prepared for the U.N. Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, U.S. Government Printing Office, Washington, D.C.

Table 72

INTENSITY OF FLOOR SPACE USE PER EMPLOYEE AND 1,000 RS. VALUE ADDED FOR SELECTED INDIAN INDUSTRIES

Floor Space/Rs. 1,000 Value Added	Floor Space/Employee: Very High 350 sq feet & Over	High 175-349 sq feet	Medium 125-174 sq feet	Low 75-124 sq feet	Very Low Less Than 75 sq feet
Very high					
100 sq feet & over	Textile finishing and processing-composite process Tanneries and leather finishing Casting of sewing machine parts Edible oils-solvent extraction Cold storage Cotton textiles-power looms Games & sports goods Edible oils-oil expellers Rice mills Starch	Crushers & expellers Electric carbon Conduit pipes Paper board & straw board Hand pumps Utensils Textile finishing and processing-single process	Cast iron pipes		
High					
70-99 sq feet	Flour mills Abrasives	Chaff cutters & spare parts Internal combustion engines	Auto parts Drugs & pharmaceuticals Switchgears		
Medium					
50-69 sq feet	Iron & steel re-rolling with electric furnace	General purpose machine tools Complete sewing machines Bolts, nuts, nails, screws etc. Bakery products	Wheat threshers Air & gas compressers	Non-electric household equipment Canning & preserving of fruits & vegetables Conveying equipment	
Low					
30-49 sq feet	Chaff cutter blades	Scientific instruments Power driven pumps Hand tools Rubber bearings Knitting mills-woolen hosiery Sugar machinery Iron and steel re-rolling		Electric equipment Weights	Storage batteries Paper for packaging Mathematical, surveying & drawing instruments
Very low					
Less than 30 sq feet	Inorganic chemicals Iron and steel structurals-light	Metal containers Bicycles Paints, varnishes and lacquers Electrical cables and wires	Plastic moulded goods Harrows, cultivators & plows Insecticides, fungicides & weedicides Precision & special machine tools	Hume pipes and other cement & concrete products Gas manufacture Rubber footwear Bushes Hurricane lanterns	Dehydration of fruits & vegetables Dusters & sprayers Electrical lamps Sanitary & plumbing fixtures Transformers Artificial leather & oilcloth Surgical instruments Electrical motors Small & cutting tools Wireless communication apparatus Metal furniture & fixtures Optics

Source: Field survey.

combustion engines, sewing machines, machine tools, power driven pumps, hand tools, and sugar machinery. Another group which stands out clearly is industries which have fabrication, assembly, pressure, or wire drawing operations. In this category would be included bicycles, conduit pipes, metal containers, bolts and nuts, and utensils. Among other high space-using industries are paper board and straw board, electric cables, paints and varnishes.

Contrasted with these two groups are very low space-using industries. A great number among these are precision industries, whose main requirement is skill rather than space. Instances in this category are optics, wireless communication apparatus, small and cutting tools, electric motors, surgical instruments, electric lamps, transformers, storage batteries, and mathematical and surveying instruments. Other industries are sporadic cases of low use of floor space. Sanitary and plumbing fixtures and hume pipes manufacturing, although extensive space-using industries, require less covered space and for this reason fall in the category of low space-using industries.

Interesting results are observed when floor space per employee for different industries is juxtaposed with employees per Rs. 1,000 value added. The latter has been assumed to be one of the many indicators of labor intensive nature of the industry. It would be seen that by and large, high space-using industries are less labor intensive. Rolling with electric furnace, flour mills, abrasives, inorganic chemicals, light structurals, and rice mills are clear examples of this group. A contrasting situation is presented by low space-using industries which have a high content of labor. Significant in this category are mathematical and surveying equipment, electric lamps, storage batteries, and paper for packaging. Dehydration is atypical in the sense that it has a special requirement of manual employees in several stages. Besides these two contrasting situations, there is another group of industries which has a high labor content as well as high floor space use. Examples are leather tanning, conduit pipes, paper board and straw board, and crushers and expellers. A number of instructive conclusions follow from this analysis.

1. Processing industries are space extensive. Other high space-using industries are those whose operations require heavy furnaces or are hazardous in nature.

2. Precision requiring industries are low space users.

3. In the machinery and metal group of industries, there is a tendency for floor space per worker to decline with proportionately greater usage of machining and assembly operations.

4. There is an inverse correlation between labor intensity and floor space for a great many industries.

5. Leather tanning, paper board, crushers and expellers, conduit pipes, hand pumps fall in the category of high labor and floor space use.

Power

Power use levels of different industries are shown in terms of unit consumption and connected load. Connected load shows the overall magnitude of the factory requirement while kwh consumption measures the intensity of energy use. The relation between connected load and kwh consumption is referred to as the power use factor* showing the intensity of the use of motors by the firms. A high power use factor is not necessarily a measure of efficiency since the use of motors is determined by the type of manufacturing operations involved. Table 73 gives clusters of industries with different levels of power use per employee and Rs. 1,000 value added.

It is observed that kwh consumption per employee is very high for industries engaged in single process operations, such as rice and flour milling, edible oils, starch, cold storage, as also for rolling and re-rolling. Consumption levels are high for industries operationally related to the use of electric welding (light structurals, sugar machinery), heat treatment (chaff cutter blades, nuts and bolts), hydraulic presses (rubber footwear, utensils), and for other processing industries such as textile finishing and textile power looms. Storage batteries, and electric carbons are high power-using industries. Contrast may be observed from the groups having low kwh requirements--i.e., less than 500 kwh per employee and 300 kwh per Rs. 1,000 value added. These fall in to three process groups. First are those which are highly precision and skill oriented industries but have a use of fractional or low horsepower motors. Optics, electric lamps, scientific instruments, wireless communication apparatus, and mathematical and surveying equipment are typical of this process group, having low intensity of power use. Second is a larger category where casting operations are significant, tending to lower the average power requirements. Internal combustion engines, cast iron pipes, crushers and expellers, non-electric household equipment, hand pumps, casting of sewing machine parts, air and gas compressors, weights, chaff cutter and parts, general purpose machine tools, and power driven pumps are examples of this group. The third group is a miscellaneous category where hand operations outweigh or equal the machine processes. For instance, hurricane lanterns (assembly), canning and preservation (cleaning, peeling, and separation of various kinds of vegetables require a large number of persons), sanitary and plumbing fixtures, and drugs and pharmaceuticals (mixing operation predominantly) have a great use of hand processes at various stages of production.

Kwh consumption per unit of Rs. 1,000 value added gives a slightly different order of intensity. This is largely explained by the value added differentials between the various industries. One instance of the effect of value added may be appropriate here. Consider the textile processing and finishing industry versus the manufacturing of chaff cutter blades; one is a processing unit performing calendering, sizing, and dyeing of textile yarn and fabrics, while the other makes chaff cutter blades by cutting

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* See page 204.

FOR SELECTED INDIAN INDUSTRIES

Consumption/Rs. 1,000 Value Added	Power Consumption/Employee: Very High 3,000 kwh and Over	High 1,000-2,999 kwh	Medium 500-999 kwh	Low 300-499 kwh	Very Low Less Than 300 kwh
Very high					
700 kwh & over	Edible oils-solvent extraction Edible oils-oil expellers Manufacture of gas Rice mills Starch Iron & steel rerolling with electric furnace Iron and steel rerolling Flour mills	Textile finishing and processing-single process Storage batteries Electric carbon Textile finishing and processing-composite process			
High					
500-699 kwh	Insecticides, fungicides & weedicides Electrical cables and wires	Utensils Artificial leather & oilcloth	Paper for packaging Paper board and straw board		
Medium					
300-499		Plastic moulded goods	Dehydration of fruits and vegetables Tanneries and leather finishing		
Low					
100-299 kwh		Cotton textiles-power looms Bolts, nuts, nails, screws etc. Rubber beltings Sugar machinery Bushes Chaff cutter blades Abrasives Rubber footwear	Surgical instruments Games & sports goods Small & cutting tools Complete sewing machines Harrows, cultivators & plows Metal containers	Crushers & expellers Auto parts Conduit pipes Nonelectric household equipment Hand pumps Canning and preserving of fruit & vegetables Sanitary & plumbing fixtures Conveying equipment Chaff cutters & spare parts General purpose machine tools Electric equipment Casting of sewing machine parts Wheat threshers Weights Internal combustion engines Hume pipes and other cement & concrete products Air & gas compressors	Cast iron pipes Drugs and pharmaceuticals Switchgears
Very low					
Less than 100 kwh		Iron and steel structurals-light	Paints, varnishes & lacquers Precision & special machine tools	Hurricane lanterns Electrical motors Metal furniture & fixtures Power driven pumps Bakery products Bicycles	Mathematical, surveying & drawing instruments Dusters & sprayers Electrical lamps Transformers Wireless communication apparatus Scientific instruments Hand tools Knitting mills-woolen hosiery Optics

Source: Field survey.

special steels to specifications, and by sharpening and heat treating processes. The kwh consumptions for the two plants are 2,029 kwh and 1,828 kwh per employee, respectively, which is a relatively low difference. When these figures are translated in terms of value added, the differences in value added for the two industries appear sharply, so as to give two ranges of power consumption levels: 976 kwh for textile processing and 219 kwh for blades per Rs. 1,000 value added. The value added percentage to gross production is 25.1 for textile finishing and 34.3 for chass cutter blades.

Table 74 gives clusters of industries arranged by intensity of power use and connected load per employee. It is observed from the table that the intensity of power use as shown by kwh consumption levels is closely related to connected load requirements. High power using industries generally have high intensities of connected loads, and the reverse equally holds valid. Shifts, where observed, occur in the immediately lower or higher category. An instance in the table is the cluster of industries making electric carbons, abrasives, light structurals, and textile finishing and processing, whose consumption per employee is shown to be high as against the connected loads which are very high, over 2.50 kw per employee. This could imply that either (1) efficiency achieved in the use of connected load motors is not as high as is noted from the clusters having identical use levels; or (2) manufacturing operations in these industries compel the connected loads to remain unused for a portion of the time. The example of the bicycle industry which has a low consumption but a high connected load amplifies this point. In the manufacture of bicycles, electroplating is one of the important power using operations requiring substantial load. This load when idle is not interchangeable with other manufacturing operations as in machine shops; it is used two or three times a week, with the load idle for the rest of the period. Thus the connected load per employee remains high while consumption levels over a period of time are relatively low. The same explanation holds for hand tools, which require heat treatment in a discontinuous way. This table is significant in judging the efficiency levels of connected loads which are achievable by different kinds of industries, and in setting up overall energy requirements.

It is instructive to examine connected load requirements in terms of labor or capital intensity of the firms, given in Table 75. Labor or capital intensity is taken to be indicated by employees per Rs. 1,000 value added. As generally understood, there is an inverse correlation between power use and labor use, in the sense that industries requiring a large number of employees per unit of net output have a low connected load. An examination of the table confirms this. Three types of clusters are identified here. First is the cluster of industries which have low connected load per employee and large labor content per Rs. 1,000 value added. These are the industries which we identified above as having significant casting operations (expellers and crushers, cast iron pipes, hand pumps, nonelectric household equipment); having many more hand and assembly operations than machine operations (dehydration; mathematical, surveying, and drawing instruments; electric lamps); and having a mixing

POWER CONSUMPTION AND CONNECTED LOAD PER EMPLOYEE FOR SELECTED INDIAN INDUSTRIES

Connected Load/Employee	Power Consumption/Employee: Very High 3,000 kwh and Over	High 1,000-2,999 kwh	Medium 500-999 kwh	Low 300-499 kwh	Very Low Less Than 300 kwh
Very high 2.50 kw & over	Starch Edible oils-solvent extraction Cold storage Edible oils-oil expellers Rice mills Iron and steel rerolling with electric furnace Iron and steel rerolling Flour mills Electrical cables and wires Gas manufacture	Electric carbon Abrasives Iron and steel structurals-light Textile finishing and processing-composite process			
High .80-2.49 kw	Insecticides, fungicides & weedicides	Textile finishing and processing-single process Utensils Cotton textiles-power looms Plastic moulded goods Rubber beltings Sugar machinery Pubber footwear Chaff cutter blades Artificial leather & oilcloth	Games and sports goods Small and cutting tools Paints, varnishes and lacquers Precision & special machine tools	Bicycles	Hand tools
Medium .50-.79 kw	Gas	Bolts, nuts, nails, screws, etc. Bushes	Paper board & straw board Surgical instruments Complete sewing machines Metal containers Paper for packaging	Conduit pipes Conveying equipment Chaff cutters and spare parts Gereral purpose machine tools	
Low .30-.49 kw			Harrows, cultivators and plows Inorganic chemicals Tanneries and leather finishing	Auto parts Sanitary & plumbing fixtures Wheat threshers Electric motors Internal combustion engines Hume pipes and other cement & concrete products Metal furnishture & fixtures Power driven pumps Bakery products Air & gas compressors	Wireless communication apparatus Scientific instruments Transformers
Very Low Less than .30 kw			Dehydration of fruits and vegetables	Crushers & expellers Nonelectric household equipment Hand pumps Canning & preserving of fruits & vegetables Electrical equipment Casting of sewing machine parts Hurricane lanterns Weights	Cast iron pipes Mathematical, surveying & drawing instruments Dusters & sprayers Drugs & pharmaceuticals Electrical lamps Switchgears Knitting mills-woolen hosiery Optics

Source: Field survey.

Table 75

CLUSTERS OF SELECTED INDIAN INDUSTRIES BY CONNECTED LOAD AND LABOR INTENSITY

Employees/Rs. 1,000 Value Added	Connected Load/Employee: Very High 2.50 KW and Over	High .80-2.49 KW	Medium .50-.79 KW	Low .30-.49 KW	Very Low Less Than .30 KW
Very low					
Less than .150	Re-rolling with electric furnace Iron and steel re-rolling Flour mills Abrasives Electrical cables & wires Iron & steel structurals-light Starch	Rubber footwear Sugar machinery Bicycles Paints, varnishes and lacquers Chaff cutter blades Precision & special machine tools	Bushes	Air and gas compressors Inorganic chemicals	Optics
Low					
.150-.249	Rice mills Manufacture of gas	Insecticides, fungicides & weedicides Plastic moulded goods Rubber beltings Hand tools	Metal containers Complete sewing machines Bolts, nuts, nails, screws, etc.	Harrows, cultivators & plows Power driven pumps Scientific instruments Bakery products Wireless communication apparatus Metal furniture & fixtures Hume pipes and other cement & concrete products	Knitting mills-woolen hosiery
Medium					
.250-.399	Cold storage Edible oils-oil expellers Edible oils-solvent extraction	Cotton textiles-power looms Small & cutting tools Games & sports goods	Surgical instruments General purpose machine tools	Electrical motors Internal combustion engines Transformers Wheat threshers	Weights Electric equipment Hurricane lanterns Casting of sewing machine parts
High					
.400-.599	Textile finishing and processing-composite process	Utensils Artificial leather & oilcloth	Chaff cutters & spare parts Conveying equipment Paper board and straw board Conduit pipes	Tanneries and leather finishing Sanitary & plumbing fixtures	Dehydration of fruits & vegetables Mathematical surveying & drawing instruments Electric lamps Canning and preserving of fruits & vegetables Drugs and pharmaceuticals Non-electric household equipment Hand pumps Dusters & sprayers Switchgears
Very high					
.600 and over	Electric carbon	Textile finishing and processing-single process Storage batteries	Paper for packaging	Auto parts	Cast iron pipes Crushers and expellers

Source: Field survey.

process (drugs and pharmaceuticals). Second is a cluster of rolling and rerolling, light structurals, flour and rice milling, rubber footwear, sugar machinery, bicycles, chaff cutter blades, etc., which require low labor per Rs. 1,000 value added and high connected load. Low labor requirements per unit of value added signify capital intensity of these industries. Even from the criterion of power use which is considered to coincide with capital employed, these are high capital requiring industries. The third group includes a few remaining industries at the extremes: (1) low power and low labor use, and (2) high power and high labor use. Notable in this category are optics, inorganic chemicals, electric carbon, utensils, and textile processing and finishing. One may be classed as a very low infrastructure use group of industries, while the other is a very high infrastructure use group.

The following conclusions emerge from the above analysis:

1. Processing industries have high intensity of power use as well as high connected load.

2. High connected loads are associated with industries requiring electric welding, heat treatment, furnaces and electroplating. Shifts in kwh consumption levels are observed for industries which use these processes in a discontinuous way.

3. Industries having fewer employees per Rs. 1,000 value added are power intensive, with the exception of precision industries such as optics, air and gas compressors, scientific instruments, and wireless communication apparatus.

4. The precision group of industries are low power users, having a greater use of fractional or low horse power motors.

Transportation

Transportation here refers to the demand that different industries place on the transportation system--both intracity and intercity. In this sense, it includes (1) tonnage of raw materials and finished products which must move over the city road system on account of different industries, and (2) tonnage procured and sent outside the city where industry is located, giving rise to demands on either rail or intercity road transport. Table 76 shows the group of industries by their intensities of use of the city road system, intensity of use being measured by the total tonnage coefficients.

It is observed from the table that flour and rice mills, cold storage, edible oils, textile processing and finishing, starch, inorganic chemicals, hume pipes, and steel rerolling are heavy transport user industries. This is a group already identified as also power and space intensive. Manufacturing operations in these industries are relatively simple, and highly mechanized, and value added by manufacturing is low. Incidentally, these

Table 76

CLUSTERS OF SELECTED INDIAN INDUSTRIES BY TONNAGE AND LABOR INTENSITY

Employees/Rs. 1,000 Value Added	Tonnage Per Employee: Very High 50 Tons & Above	High 25-49 Tons	Medium 10-24 Tons	Low 5-9 Tons	Very Low Less Than 5 Tons
Very low					
Less than .150	Flour mills Inorganic chemicals Starch Iron and steel re-rolling	Sugar machinery Bicycles	Rubber footwear Iron & steel re-rolling with electric furnace Chaff cutter blades Paints, varnishes & lacquers	Bushes Abrasives Precision and special machine tools Air and gas compressors	Optics
Low					
.150-.249	Hume pipes and other cement & concrete products Gas manufacture Rice mills	Bolts, nuts, nails, screws, etc. Harrows, cultivators, & plows Knitting mills-woolen hosiery Insecticides, fungicides & weedicides	Complete sewing machines Rubber beltings Bakery products	Hand tools Metal furniture & fixtures Power driven pumps Metal containers	Wireless communication apparatus Plastic moulded goods Scientific instruments
Medium					
.250-.399	Edible oils-solvent extraction Cold storage Edible oils-oil expellers	Weights	General purpose machine tools Casting of sewing machine parts Cotton textiles-power looms	Wheat threshers Games and sports goods Internal combustion engines Surgical instruments	Electric equipment Transformers Hurricane lanterns Electrical motors
High					
.400-.599	Artificial leather & oilcloth		Paper board & straw board Non-electric household equipment Dehydration of fruits and vegetables Hand pumps Canning and preserving of fruits and vegetables Chaff cutters & spare parts	Conduit pipes Textile finishing and processing-composite process Utensils Switchgears Conveying equipment	Mathematical, surveying & drawing instruments Drugs and pharmaceuticals Electric lamps Sanitary and plumbing fixtures
Very high					
.600 & over	Textile finishing & processing-single process		Cast iron pipes	Auto parts	Storage batteries Electric carbon Paper for packaging

Note: Data not available for Dusters and sprayers; Small and cutting tools

Source: Field survey.

are direct raw-material consuming industries, as distinct from semimanufactured materials. Transport costs are substantial and, as we can see, this group of industries tends to be located near the sources of raw materials or centers of consumption.

With a decline in the use-intensity of transport, industrial products become greatly mobile, often leading to concentration of industries at a few distribution points. Transport of the finished products is relatively convenient and its cost in total cost of production is lower. These products are also of the industrial type whose degree of perishability and decomposition is generally low. Notable in this large category are auto parts, utensils, switchgears, surgical instruments, hand tools, bushes, precision machine tools, storage batteries, electric carbon lamps, electric motors, wireless communication apparatus, and scientific instruments. In short, these are not transport oriented industries.

There is a middle range of industries generating transportation demand of 10-24 tons. For this group, pulls are exerted both by raw material sources and by marketing or consuming centers, and hence, in these cases, transport costs of obtaining the raw materials need to be compared with transport costs of sending the finished products. Particular instances are paper board and straw board, dehydration of vegetables and fruits, and power looms.

Among the industries using rail transport, more metal and machinery industries use it than any other types of industry. For instances, rolling and rerolling, conduit pipes, cast iron pipes, metal utensils and containers, hurricane lanterns, hand tools, weights, structurals, and sugar machinery use rail transport for more than 60 percent of their tonnage. This group uses bulky raw materials such as pig iron, coke, and sheet metal. An exception in this category is major agricultural implements which are distributed by road transport in the rural hinterland. Contrasted to this broad category are canning and preserving of fruits and vegetables, rice mills, and tanneries and leather finishing whose main mode of transport is intercity roads. The industry characteristics in their case require collection and speedy transportation of raw materials to the manufacturing plants, and this is provided by road transport. However, these are broad indications only; it is not possible to generalize the mode of transport for any types of industries because the mode depends on a variety of factors.

Water

Water is used for many purposes by industries. It is used by a large number of industries for cooling purposes to achieve normal temperature for effective operations. Water is important in several machining processes that produce heat by turning, drilling, milling, and grinding; in many other processes, water enters directly in solutions or mixtures containing the materials being processed. Table 77 shows clusters of industries by their use levels of water.

Table 77

CLUSTERS OF SELECTED INDIAN INDUSTRIES BY WATER CONSUMPTION

Water Consumption Per Day/Employee				
Very High 250 Gallons and Over	High 50-249 Gallons	Medium 10-49 Gallons	Low 4-9 Gallons	Very Low Less Than 4 Gallons
Starch	Bicycle	Bushes	Paints, varnishes and lacquers	Optics
Sugar machinery	Iron and steel re-rolling	Electric cables and wires	Chaff cutter blades	Air and gas compressors
Rubber footwear	Iron and steel structurals - light	Inorganic chemicals	Abrasives	Precision and special machine tools
Iron & steel re-rolling with electric furnace	Hume pipes	Complete sewing machines	Scientific instruments	Metal furniture and fixtures
Flour mills	Power driven pumps	Bakery products	Rubber beltings	Harrows, cultivators, and plows
Dehydration of fruits and vegetables	Manufacture of gas	Bolts, nuts, screws, and nails, etc	Cotton textiles - power looms	Rice mills
Artificial leather and oilcloth	Plastic moulded goods	Electric equipment	General purpose machine tools	Knitting mills - woolen hosiery
Paper board and straw board	Edible oils - oil expellers	Cold storage	Wheat threshers	Metal containers
Textile finishing and processing-single process	Edible oils - solvent extraction	Internal combustion engines	Transformers	Insecticides, fungicides and weedicides
	Chaff cutters and spare parts	Weights	Dusters and sprayers	Hand tools
	Tanneries and leather finishing	Games and sports goods	Switchgears	Wireless communication apparatus
	Canning and preserving of fruits and vegetables	Sanitary and plumbing fixtures	Cast iron pipes	Surgical instruments
	Textile finishing and processing - composite process	Drugs and pharmaceuticals	Crushers & expellers	Casting of sewing machine parts
		Utensils		Hurricane lanterns
		Electric lamps		Electrical motors
		Auto parts		Small and cutting tools
		Electric carbon		Mathematical, surveying and drawing instruments
				Conveying equipment
				Nonelectric household equipment
				Conduit pipes
				Paper for packaging
				Storage batteries

Source: Field survey.

It is observed from the table that industries with high water use belong to different process groups, because the purposes for which water is needed vary from industry to industry. Textile finishing and processing, paper board and straw board, tanneries and leather finishing, starch, and canning, preserving, and dehydration of fruits and vegetables form one category of use where water is extensively used directly in processing and washing materials. The quality of water required is as important as quantity for these industries. Bicycles, power driven pumps, and chaff cutters and spare parts constitute a separate group, since in these industries, water use is related to electroplating, casting, and machining operations. For the remaining industries in the high water-use group, water is mainly required for temperature reduction purposes. These industries have intense and continuous need for water that is reusable.

The cluster of industries having a medium level of water requirements is largely representative of the group requiring casting and machining operations. Low water-using industries include precision industries and those in which fabrication and assembly of the products are significant.

When intensities of water use are examined in relation to power and transport use, it is found that by and large, industries having greater use of water are also power consuming and high users of transport. Examples include edible oils, flour mills, textile finishing and processing, paper board and straw board, rolling with electric furnace, and rubber footwear.

Industrial Wastes

This analysis of water use leads to the question of industrial waste disposal. In the absence of data on the composition and quantities of waste by different industries, we are able to give only broad indications on the seriousness of waste disposal problems created by different kinds of industries. Three clusters of industries are identified as producing wastes of different characteristics:

- Industries where water enters directly into solutions and mixtures, producing organic wastes and suspended solids. These are textile finishing and processing, paper board and straw board, leather and leather finishing, and canning and dehydration of fruits and vegetables.

- Industries that produce toxic wastes in such processing as electroplating, derusting, and annealing. These wastes, because of high acid and metal content, are extremely dangerous even though their volume is not great. Insecticides also produce toxic wastes.

- Industries that use steam power, where the problem is to dispose of large volumes of water. Examples are foundry and fabrication operations.

As a means of focusing the conclusions of the preceding analysis, it is perhaps useful to reiterate the relationships between industries and intensities of infrastructural uses in a somewhat modified form. Four different types of relationships were evidenced in our data examination.

1. Industries with high use intensity of physical infrastructure inputs. This category of industries includes edible oils by expellers and solvent extraction, cotton textiles-power looms, cold storage, textile finishing and processing, tanneries and leather finishing, flour and rice mills, starch, abrasives, iron and steel rolling and structurals, electric cables and wires, electric carbon, and manufacture of gas. These industries characteristically perform single operations or a continuous sequence of operations, rather than multiple and complex tasks. Their technology may be specialized but labor skills are relatively simple. Capital requirements as well as costs of physical infrastructure are substantially higher, but this does not necessarily mean that labor participation as an element of value added is low in these manufacturing lines.

2. Industries with low use intensity of physical infrastructure inputs. Compared with category 1 above, these industries with low infrastructure use are characterized by precision, skill, work specialization, and more diversified technology. Examples are: electric lamps, surgical instruments, electric motors, wireless commun cation apparatus, optics, mathematical, surveying and drawing instruments, electric equipment, knitting mills, drugs and pharmaceuticals, scientific instruments, and hurricane lanterns. The requirements of skilled employees in this category are far greater than for the first category, as indicated by Table 78.

   In addition to the precision type of industries, others with uniform low infrastructure are dusters and sprayers, and metal furniture and fixtures.

3. Industries oriented to single infrastructure inputs. This group primarily consists of industries engaged only in casting or other operations which need floor space in preference to any other infrastructure. These are crushers and expellers, castings of sewing machine parts, hume pipes and other cement products, conduit pipes, and games and sport goods. Canning and preserving of fruits and vegetables is another example whose main requirement is clean water source.

4. Industries that have a medium level of use requirements for physical and social infrastructure.

Orientation or indifference of industries to city size and infrastructure, as stated in this section, is not without a series of reservations. The economic realm provides far greater options in location than are offered by "clusters" related to either city size or infrastructure. Markets,

Table 78

PERCENTAGE OF SEMISKILLED AND SKILLED WORKERS*
IN SELECTED INDUSTRIES

Industry	% of Semiskilled to Total	% of Skilled to Total
Flour mills	31	8
Rice mills	45	20
Edible oils	25	4
Starch	27	9
Cold storage	19	12
Power looms	6	1
Textile finishing and processing	11	2
Iron and steel rerolling	38	2
ugs and pharmaceuticals	22	17
Knitting mills	34	51
Electric lamps	45	7
Electric motors	70	7
Surgical instruments	44	--
Wireless communication apparatus	22	8
Optics	39	15
Scientific instruments	61	28

* Assumptions: semiskilled--wages of Rs. 100-199 per month; skilled--Rs. 200 and over per month.

industry linkages, and agglomeration economies are only a few illustrations of influences that are embedded in the competitive spectrum of industrial development. Apt manifestations of industrial linkages are: the recent response of the knitting machinery and woolen yarn industries in Ludhiana to the demands of the hosiery industry; and the response of textile calendering and sizing to the growing power loom sector in Maunath Bhanjan. The cardboard industry developed in Saharanpur and Kanpur to meet the immediate demands of cigarette and textile packings offers an instance of market as the main force in location. These added location factors which have stayed out of our formulation of infrastructure characteristics provide a perspective within which the preceding analysis of this chapter should be viewed.

Urban Choices for Industrial Location

In analyzing choices of industrial locations as related to city size in the first section of this chapter, we identified the nature and types of (1) ubiquitous industries and products more or less common to all sizes of cities; (2) industries characteristic respectively of small, medium, and large cities; and (3) industries drawn to resources, having little systematic relation to any except perhaps the small size cities. In the second and third sections of this chapter, we examined levels of infrastructural requirements of a much larger group of industries, based on plants which exhibit somewhat higher levels of technology and management than the average plant in these industries in the 18 cities.

The main area of concern in the present section is to coalesce the two analyses, so as to (1) introduce the dynamic concept of urban choice, and (2) provide coordinated illustrative or indicative sets of industries which would be locationally appropriate to different sizes of cities in a time perspective of some ten years. These two propositions imply that choices of locations which appear rational today may change over time, that what today is characteristic of particular size groups may become ubiquitous, and that the definition of ubiquity itself may be broadened. In other words, a new or modified set of relationships between industrial locations, city size, and infrastructure may grow in the time span that we are looking into.

As evidence for such choices, we summarize the locational characteristics which can be expected to favor relatively ubiquitous city size location for some types of industries, or encourage orientation to small, medium, or large cities for other industries. This reasoning leads to the identification of tangible industry groupings of each kind, presented as Lists A to D in Table 79, with explanatory comments below.

We earlier characterized ubiquitous industries as (1) being largely nonbasic (i.e., not serving external markets), (2) having high transport cost or low propensity of commodity flows, and (3) having low linkages over space, in the sense that the nodes of production and consumption almost coincide. The new ubiquitous set, List A, meets the above characteristics, inasmuch as three groups are clearly identifiable: hand pumps,

Table 79

INDICATIVE SETS OF INDUSTRIES BY CITY SIZE

Core or Ubiquitous: List A

Flour mills	Utensils
Bakery products	Hand tools
Edible oils-oil expellers	Sanitary and plumbing fixtures
Cotton textiles-power looms	Weights
Textile finishing and processing-single	Power driven pumps
Metal furniture and fixtures	Harrows, cultivators, and plows
Paints, varnishes, and lacquers	Wheat threshers
Insecticides, fungicides, and weedicides	Hand pumps
Hume pipes and other cement products	Electric equipment
Cast iron pipes	Plastic molded goods

Small City: List B

Canning and preserving of fruits and vegetables	Paper board and straw board
Cold storage	Crushers and expellers
	Casting of sewing machine parts

Medium City: List C

Dehydration of fruits and vegetables	Dusters and sprayers
Edible oils-solvent extraction	Chaff cutters and spare parts
Knitting mills-woolen hosiery	Complete sewing machines
Paper for packaging	Nonelectric household equipment
Rubber footwear	Switchgears
Drugs and pharmaceuticals	Transformers
Iron and steel rerolling	Electric motors
Conduit pipes	Storage batteries
Bolts, nuts, nails, screws, etc.	Bicycles
Small and cutting tools	Auto parts
Internal combustion engines	Bushes (bushings)
Sugar machinery	Scientific instruments
Conveying equipment	Mathematical, surveying, and drawing instruments
General purpose machine tools	

Large City: List D

Textile finishing and processing-composite	Precision and special purpose machine tools
Industrial rubber beltings	Chaff cutter blades
Inorganic chemicals	Electric carbon
Grinding wheels and abrasives	Electric lamps
Special steels-rolling with electric furnace	Electric cables and wires
Iron and steel structurals	Wireless communication apparatus and equipment
Metal containers	Surgical instruments
Hurricane lanterns and torches	Optics
Air and gas compressors	Manufacture of gas

weights, sanitary and plumbing fixtures, metal furniture and fixtures, and hand tools are nonbasic; flour mills, edible oils, hume pipes and cast iron pipes have significant transport costs; and the remaining industries in List A have markets fairly localized or extended to the immediate hinterland. New linkages that we envisage to this minimum core are power driven pumps, related to development programs for tubewells, and paints, varnishes, and household electric equipment meeting new urban demands. Infrastructure traits of those industries are of medium intensity. None of the industrial groups (excepting those identified as transport oriented) are heavy infrastructure users. They do not present problems of location in any size city on account of any peculiarities of infrastructure use.

Small cities at present show locational preference for resource-based industries. These cities are the first urban points in rural areas where processing of agricultural or other produce can be undertaken without heavy transport costs or risk of perishability. Besides raw material orientation, processing industries show infrastructure characteristics of being either space extensive or heavy water users. Small cities are particularly oriented to these facilities. List B has been constructed from these considerations.

Prospective industries for medium cities of 100,000 to 250,000 population are examined with particular attention to their potential contribution to a more diversified manufacturing structure. The low coefficients of industrialization for this city size class in Punjab and Uttar Pradesh have been noted. This is obviously not a permanent structural feature. Many cities of the 50,000 to 100,000 size class, which has industrialization coefficients of 1.44 in Punjab and .93 in Uttar Pradesh, will carry their higher incidence of manufactures as they make the transition beyond 100,000 inhabitants. Cities of this size in Uttar Pradesh now have location quotients of 1.63 for metal products and 1.07 for machinery. Attention to new linkages* can strengthen the development of external economies provided by such industries in cities growing to medium size.

With this transitional phase in view, industries oriented to two types of linkages are visualized for medium cities in List C. In linkage with ubiquitous or core industries of the volume sustained by medium cities, industries such as paper for packaging, iron and steel rerolling, bolts, nuts, nails and screws, small and cutting tools, and general purpose machine tools can be expected to develop. A more complete breakthrough would be achieved with growth of related machinery and metal manufactures, complementary in their operations and creating demands for an increasing variety of specialized parts producers and subcontracting units. List C industries

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* The need for companies to cluster together because of external economies and to be linked for contact has been described in the phrase "communication-oriented industries." See P. Sargant Florence, Economics and Sociology of Industry, a Realistic Analysis of Development, C. A. Watts and Co. Ltd., London, 1964.

such as internal combustion engines, conveying equipment, sewing machines, and switchgear represent such opportunities.

Excluded from List C are high volume or precision industries, such as electric steel furnaces and special purpose machine tools, which are expected to benefit particularly from the central distribution and marketing functions of a major city. Orientation of such industries to large cities is suggested in List D, representing further specialization and extension of agglomeration economies.

V INFRASTRUCTURE COSTS AND CITY SIZE: A TEST OF THE RESEARCH HYPOTHESIS

We now approach the central focus of this research: estimation and analysis of the specific costs of incremental infrastructure that would be required for a major industrial expansion in five test cities of different size. As a basis for this procedure and for selecting the five test cities, a systematic review of existing infrastructure in the 18 surveyed cities is first required. Successive sections will examine construction cost levels as related to city size; establish an industry mix as the basis for infrastructure requirements, describe criteria for site selection and steps for determining off-site facility requirements in the test cities; define facility standards used as the basis for cost estimation; and, finally, analyze the pattern of costs in order to reach conclusions on the research hypothesis.

Existing Infrastructure Development and Use Levels

The size, stage of development, and level of utilization of existing facilities were discussed in Chapter II as factors influencing the costs of equipping cities for additional industry. To test the effects of city size on these factors, information obtained from field discussions with public agencies in the 18 cities, and from published reports, is presented in the City Inventory, Table 80.

Population and Land Use

The demographic and land use data on the first page of the City Inventory set the stage for examining the development and use of physical facilities, presented on subsequent pages.

Population. About one-half of the field cities follow a trend of higher population growth rate with larger city size. Significant deviations from the trend are Modinagar and Jagadhri-Yamunanagar, which doubled in population from 1951 to 1961, and to a lesser extent, Ludhiana. These are cities that experienced unprecedented industrial growth and expansion during the period. The lowest growth rates are observed for city size group 50,000-100,000 where, except for Maunath Bhanjan, the annual population increase does not exceed 2 percent.

Working Force. The size of the working force with respect to the total population is within a relatively narrow range of 27 to 33 percent for as many as 16 cities. Exceptions are Maunath Bhanjan at 45 percent

Population, Area, Houses and Employment

City	Corporate Population: Total 1951 (000)	Total 1961 (000)	Total 1967* (000)	1967* (000)	Percent Increase 1951-61 (%)	Percent Increase 1961-67 (%)	Corporate Area: Total 1951 (acres)	Total 1961 (acres)	Total 1967 (acres)	Density 1951 (persons per acre)	Density 1961	Density 1967	Occupied Residential Houses 1961 (no.)	Total Working Force 1961 (no.)	% of Population 1961 (%)	Manufacturing Workers‡ Total 1961 (no.)	% of Work Force 1961 (%)	Employment in Registered Factories 1965 (no.)
npur	636	881	1,070	1,200	39	21	11,155	64,640	61,610	57	14	17	146 965	286 11[illegible]	33	103,301	36	82,929
ranasi	342	471	573	530	38	22	5,459	18,240	18,240	63	26	31	48,663	150,361	32	17,369	12	9,401
dhiana	154	211	323	n a	59	32	2,880	4 858	10 140	53	50	32	47,267	72 369	30	26,081	36	18,227
reilly	190	251	301	278	34	20	10,012	5,274	12,800	19	48	24	33 600	71,115	28	16,197	23	8,733
llundur	169	223	266	315	32	20	5 760	10,880	10,880	29	20	24	40,759	60 191	27	16 315	27	10 945
rakhpur	132	180	216	223	36	20	9,600	9 600	9,600	14	19	22	32 161	57 311	32	9 911	17	12,205
haranpur	146	185	212	200	25	15	1,000	6,2[illegible]0	7,680	37	30	28	30,261	5[illegible],773	30	11 706	27	7,771
bala (Town Group)§	152	182	202	199	[illegible]0	11	11,110	11,110	n a	14	16	n a	35 017	5[illegible],[illegible]	3[illegible]	7,32[illegible]	13	2,634
tiala	98	125	115	116	28	16	8,320	8 320	8,320	12	15	1[illegible]	2[illegible],512	36,[illegible]20	29	4,989	11	1,445
gadhri-Yamunanagar	40	84	132	141	113	57	3,430	3,430	3,430	12	25	36	17,173	26,80[illegible]	32	11,298	12	7,101
izabad	77	84	88	92	9	5	8,154	7,782	7,782	10	11	11	15 916	26 170	31	2,805	11	1,190
rnal	60	72	81	81	21	12	781	2,432	2,432	77	30	33	14,056	19 821	28	3,050	15	536
roha	59	69	76	n.a.	17	10	1,280	1 562	4,053	46	41	19	9 711	18 665	28	3 557	19	1,392
ssani	52	58	62	62	12	7	2,560	3,200	3,200	20	18	19	11,209	15,768	27	4,801	30	3,836
nath Bhanjan	35	49	60	65	40	23	320	1,920	1,920	109	25	31	6,870	[illegible] 121	15	709	3	388
pur	49	55	59	62	12	7	1,440	1,110	1,440	34	38	41	8,905	15,306	28	1,899	12	824
gwara	26	38	48	46	48	27	1,920	2,560	2 560	13	15	19	7,016	10,503	28	4,066	39	4,899
dinagar	12	24	36	n.a.	97	48	2,560	2 560	1,280	5	9	28	5,550	9,278	38	6,665	72	8,008

Straight line projection used in all computations
Local municipal estimate
Does not include household industry
Data is for town group, city population 58,000 (1951), 76,000 (1961), 90,000 (1967), area 2,150 (1961)
All data for Faizabad includes Ayodhya.

Developed Area and Land Use

City	Year	Developed Area: Area Total (acres)	Area % of 1967 Corporate Area (%)	Population Total (000)	Population Per Developed Acre (no.)	Land Use of Developed Area (percentage distribution): Residential (%)	Commercial (%)	Industrial (%)	Roads & Railways (%)	Public & Semipublic (%)	Parks & Playgrounds (%)	Vacant (%)	Other (%)
npur	1963	19,102	30	964	50	37	2	7	10	10	1	33	0
ranasi	1965	6,304	35	550	87	49	3	6	11	7	3	15	6
dhiana	1963	4,850	48	290	60	44	2	11	18	22	2	0	1
reilly	1967	5,761	45	304	53	n.a.	n.a.	n.a.	n a.	n.a.	n.a.	n.a.	n.a.
llundur	1963	2,989	27	240	80	54	2	12	17	12	3	0	0
rakhpur	1964	8,042	84	204	25	13	1	2	12	3	11	57	1
haranpur	1962	5,578	73	193	35	31	2	18	18	14	4	10	3
bala**	1963	1,520	71	79	52	57	1	3	21	16	1	0	1
tiala	1967	5,600	67	145	26	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
gadhri-Yamunanagar	1967	2,648	77	132	50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
izabad	1967	3,790	49	88	23	n.a.	n.a	n a.	n.a	n.a	n.a.	n.a.	n.a.
rnal	1967	1,160	48	81	70	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
roha	1967	950	23	76	80	n a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ssani	1967	1,434	45	62	43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
nath Bhanjan	1967	1,178	61	60	51	n.a.	n a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
pur	1966	728	51	59	81	51	4	4	16	13	4	0	8
gwara	1965	836	33	45	54	35	8	16	26	5	5	0	5
dinagar	1963	518	40	28	54	30	1	23	32	7	7	0	0

Straight line projection of corporate population for stated year.
City only

Table 80 (continued)

City	Paved Municipal Roads 1966-67: Length (miles)	Per 1,000 Persons (miles)	Per 1,000 Acres of Corporate Area (miles)	Per 1,000 Acres of Developed Area (miles)	Road Tonnage 1965-66: Terminating (000 metric tons)	Originating (000 metric tons)	Transit (000 metric tons)	Total (000 metric tons)	Terminating & Originating Tonnage/1,000 Persons (metric tons)	Total Road Tonnage per Road Mile (metric tons)
Kanpur	288.0	27	4 5	15	1,593	1,051	330	2,975	2,472	10,330
Varanasi	100.0	.17	5 5	16	513	240	456	1,209	1,315	12,095
Ludhiana	62.9	.19	6 2	13	706	394	1,699	2,799	3,406	44,502
Bareilly	143.9§§	47	11.2	25	401	183	1,592	2,176	1,922	15,123
Jullundur	91.0	.34	8.4	30	650	446	726	1,822	4,121	20,021
Gorakhpur	138.3	64	14 4	17	237	165	209	610	1,860	4,413
Saharanpur	n.a.	n.a	n a.	n.a.	324	313	301	938	3,005	n a.
Ambala (Town Group)	n a	n.a.	n a.	n.a.	395	326	1,131	1,852	3,569	n.a.
Patiala	58.3	.40	7.0	10	410	137	388	931	3,709	16,022
Jagadhri-Yamunanagar	25 3	.19	7 4	10	50@@@	310	294	653	2,724	25,828
Faizabad	87.1	.99	6 9	23	146	78	38	261	2,544	3,002
Karnal	30.0	.37	12.3	26	226	141	612	979	4,534	32,616
Amroha	11.0§§	,14	2.7	12	n a	n.a.	n.a.	n.a	n.a	n.a.
Bhiwani	22.0	35	6.9	15	n.a.	n.a.	n.a.	n.a	n a	n.a.
Maunath Bhanjan	27.9	.46	14.5	24	23	25	45	92	794	3,310
Hapur	29.5@@@	.50	20.5	41	908	88	369	1,365	16,874	46,267
Phagwara	17.0	.35	6.6	20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Modinagar	10.0	.28	7.8	19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

§§ 1965-66
@@@ Partial information; Jagadhri only
@@@ 1964-65

City	Rail Sidings: Goods Sidings (ft)	Wagon Capacity (no.)	Goods Sheds: Covered (sq ft)	Uncovered (sq ft)	Rail Tonnage: Terminating (000 metric tons)	Originating (000 metric tons)	Total (000 metric tons)	Total Tons Per 1,000 Persons (metric tons)	Municipal Expenditures 1966-67: Municipal Expenditures Total (000 Rs.)	Per Capita (Rs.)	Municipal Income Total (000 Rs.)	Per Capita (Rs.)	Octroi, Toll, & Terminal Tax Receipts Total (000 Rs.)	Per Capita (Rs.)
Kanpur	n.a.	n a.	n a	n.a.	770	216	985	921	46,601§§	44	48,841§§	46	3,322	3
Varanasi	4,562	158	53,047	19,150	1,167	177	1,345	2,315	12,700	22	11,660	20	4,602	8
Ludhiana	n.a.	198	n a	n a.	20	6	26	80	6,581	20	6,589	20	4,371	14
Bareilly	1,276	44	7,930	13 690	90	n a	n a	n a	n a	n a	n a	n a	1,935§§	7
Jullundur	625	21	8,750	5,300	281	95	379	1,125	4,632	17	4,798	18	3,085	12
Gorakhpur	n.a.	n a	n a	n.a	192	40	232	1,073	3,804	18	3,720	17	1,487	7
Saharanpur	887	31	22,700	18,260	327	67	394	1,859	4,318	20	4 621	22	1,578	7
Ambala (Town Group)	696	24	n a	n.a	302	103	405	2,006	1,651**	18**	1,117**	16**	1,008**	11**
Patiala	374	13	8,890	4,200	84	43	127	874	2,491	17	2,210	15	1,253	9
Jagadhri-Yamunanagar	580	20	n.a	n a.	278	105	383	2,899	n a	n.a.	r a	n a	n a.	n.a
Faizabad	662	31	12,900	16,840	72	13	85	968	2,216	25	2,729	31	983	11
Karnal	965	31	3,000	9,000	n a	53	n.a	n a	1,146	14	1,238	15	690	9
Amroha	812	28	n.a.	n.a	72	43	115	1,513	901	12	1,024	14	471	6
Bhiwani	1,100	30	5,120	2,560	27	9	36	581	811	13	812	13	505	8
Maunath Bhanjan	n.a.	n a.	n a.	n.a	57	6	63	1,051	922	15	837	14	520	9
Hapur	580	20	12,000	6,750	10	7	18	302	1,472	25	1,514	26	666	11
Phagwara	770	27	3,200	8,000	10	n.a.	n.a	n.a.	699	15	679	14	531	11
Modinagar	n.a.	n.a.	n.a.	n a	128	14	143	3 959	119	3	119	3	n.a.	n.a.

** City only
§§ 1965-66

Power 1966-67

City	Capacity (million volt amperes)	Capacity Factor (%)	Total Consumption: Total** (million kwh)	Total Consumption: Industrial (million kwh)	Total Consumption: Domestic (million kwh)	Per Capita Consumption: Total** (kwh)	Per Capita Consumption: Industrial (kwh)	Per Capita Consumption: Domestic (kwh)	Industrial Consumption as % of Total (%)	Low Tension Distribution Lines: Total (miles)	Low Tension Distribution Lines: Per Million KWH (miles)	Low Tension Distribution Lines: Per 1,000 Persons (miles)	Low Tension Distribution Lines: Per 1,000 Acres of Developed Area (miles)
Kanpur	117.0	46	399 6	276.8	41.1	873	259	38	69	439.0	1 1	0 41	23
Varanasi	23 7	43	75 0	35 5	21 2	131	62	37	47	143 0‡‡	1 9	0 25	23
Ludhiana	32 0§§	23	54 8	32 4	19.7	170	100	61	59	99.0‡‡	1 8	0 31	20
Bareilly‡‡	8 6	47	30.3	13 2	4.3	100	43	14	44	106 2	3.5	0 35	18
Jullundur	77 3§§	7	43.1	17 9	25.2	162	67	95	45	133 5	3 1	0 50	45
Gorakhpur	n a	n a	7 6	2 9	2 0	35	13	9	38	53 2	7.0	0.25	6
Saharanpur	n.a	n.a	11 0	5 1	5.3	52	24	25	46	n.a	n.a	n a.	n.a.
Ambala (Town Group)	6 9§§	23	11.6	4 3	3 6	58	21	18	37	67 2	5.8	0 33	44
Patiala	21 6§§	13	20.4	12 9	4 8	141	89	33	63	84 1	4 1	0.58	15
Jagadhri-Yamunanagar	17 0§§	21	27.0	19 4	2.1	205	147	16	72	81 1	3.1	0 64	32
Faizabad	n.a.	n a	5 9	2.4	2 9	67	27	33	40	58.6	10 0	0 67	15
Karnal	8.0§§	20	12 2	2 0	6.7	150	24	83	16	n.a	n a	n a	n.a.
Amroha	1 6	20	2 4	1 5	n.a	32	19	9⊗	60	9 5	4 0	0.13	10
Bhiwani	n.a.	n a.	16 0	14.1	0.9	257	227	14	88	n a.	n a	n.a	n.a.
Maunath Bhanjan	1.7	n.a.	n a.	1.0	0.5	n.a	16	9	n a.	14 3	n.a.	0.24	12
Hapur	n.a	n.a.	n n.	n a	n a.	n.a.	n a	15⊗	n a	n.a	n.a.	n.a	n.a.
Phagwara	11.6	30	25.8	23.8	1.5	538	496	32	93	71 3	2.8	1 49	85
Modinagar	21.0	33	52.0	51.1	0 6	1,444	1,419	17	98	5 0	0 1	0.14	10

** Total includes industrial, domestic & other.
‡‡ 1965-66
§§ Capacity not exclusive to city
⊗ Estimated

Water 1966-67

City	Source of Supply	Available Capacity: Total (mgd)	Available Capacity: Per Capita (gpd)	Total Daily Consumption (mgd)	Surplus Available: Total (mgd)	Surplus Available: (%)	Extent of Water Services: Area: Total (acres)	Extent of Water Services: Area: % of Corporate Area (%)	Extent of Water Services: Population: (000)	Extent of Water Services: Population: % of Corporate Population (%)	Consumption Per Population Served (gpcd)	Length of Water Mains: Total (miles)	Length of Water Mains: Per MGD Consumed (miles)	Length of Water Mains: Per 1,000 Acres Served (miles)	Sewerage 1966-67: % of City System Completed (%)
Kanpur	River, canal, underground	49 0	46	43.0	6.0	12	22,500	35	1,070	100	40	203 0	4 7	9.0	68
Varanasi	River, underground	30 0	52	22.9***	7.1***	24***	6,400	35	573	100	40	124.5	5.4	19 5	100
Ludhiana	Underground	5.1	16	4 7	0.4	8	6,692	66	215	67	22	n a.	n a.	n a.	25‡‡‡
Bareilly	Underground	3.5	12	2.1	1.4	40	9,920	78	250	82	8	39 7	18.9	4 0	31‡‡‡
Jullundur	Underground	10.0	38	7 0	3 0	30	2,000	18	160	60	44	14 2	2.0	7 1	72‡‡‡
Gorakhpur	Underground	5 4	25	3.2	2 2	41	7,680	80	223	100	14	77 6	24.3	10 1	27‡‡‡
Saharanpur	Underground	4 8	23	2.2	2.6	54	7,680	100	130	61	17	33.3	15.1	4.3	46
Ambala (Town Group)	Underground	2 9	14	2.3	0.6	21	4,155	44	155	77	15	8.8	3.8	2 1	0§§§
Patiala	Underground	3.3	23	2.6	0 7	21	6,656	80	105	72	25	n.a.	n.a.	n.a.	5‡‡‡
Jagadhri-Yamunanagar	Underground.	3.0	23	3 0	0	0	900	26	71	54	42	17 6	5.9	19.6	12‡‡‡
Faizabad	Underground	3 2	36	2 6	0.6	19	7,782	100	88	100	30	5, 7	20 7	4 2	0
Karnal	Underground	3 0	37	2 4	0.6	20	1,946	80	67	83	36	n a	n.a.	n.a.	74‡‡‡
Amroha	Underground	2.5	33	0 2	2 3	92	950	23	75	99	3	n a.	n.a	n.a.	0
Bhiwani	Canal	1.2	19	1.2	0	0	3,200	100	62	100	19	2 9	2.4	0.9	0§§§
Maunath Bhanjan	Underground	0.4	7	0.2	0.2	50	960	50	30	50	7	12.1	60.5	12.6	0
Hapur	Underground	1.1†††	19***	0.6***	0.5***	46***	728	51	62	100	10	2.6	4.3	3.6	20‡‡‡
Phagwara	Underground	0.3	6	0 1	0 2	67	117	5	4	8	25	5 5	55.0	47.0	57
Modinagar	Underground	2.0	56	n.a.	n.a.	n a	n a.	n.a.	n a.	n.a	n.a.	n.a.	n.a.	n.a.	0

⊗ Served partly by house connections and partly by public standposts
*** 1965
*** 1966
‡‡‡ Under progress, percent completed estimated
§§§ Proposed, but not yet implemented

Table 80 (concluded)

Other Public Facilities 1966-67

City	Educational Facilities: Primary Schools**** (no.)	Primary Schools: Enrollment Total (no.)	Primary Schools: Enrollment Average per School (no.)	Higher Secondary Schools**** Total (no.)	Higher Secondary Schools: Enrollment Total (no.)	Higher Secondary Schools: Enrollment Average per School (no.)	Professional Colleges (no.)	Hospitals: No. of Beds Total (no.)	Hospitals: No. of Beds Per 1,000 Persons (no.)	Telephone Connections Total (no.)	Telephone Connections Per 1,000 Persons (no.)	Fire Protection Annual Expenditures per Capita (Rs.)	Garbage & Refuse Disposal Annual Expenditures per Capita (Rs.)	Cinemas (no.)
Kanpur	724	165,901	229	70	70,856	1,012	14	1,843	1.7	9,311++++	8.7	.26	n.a.	23
Varanasi	181	36,504	202	60	35,092	585	8	965	1.7	3,696++++	6.5	.25	5.0	15
Ludhiana	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6	n.a.	n.a.	2,177	6.7	n.a.	0.8	8
Bareilly	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	n.a.	n.a.	1,428	4.7	15	0.8	12
Jullundur	n.a.	27,725	n.a.	n.a.	10,233	n.a.	4	616	2.3	3,973++++	14.9	n.a.	1.3	7
Gorakhpur	112	54,463	186	31	n.a.	n.a.	12	469	2.2	962	4.5	n.a.	3.3	10
Saharanpur	37	8,000	216	n.a.	n.a.	n.a.	2	250	1.2	879	4.1	23	0.4	9
Ambala (Town Group)	34	11,191	329	28	20,701	739	3	426	2.1	1,686	8.3	66	0.5**	8
Patiala	11	3,320	302	19	20,903	1,100	6	1,000	6.9	960	6.8	42	1.4	3
Jagadhri-Yamunanagar	26	10,564	406	9	9,071	1,008	2	126	1.0	807	6.1	25	0.3@@@	3
Faizabad	50	7,679	153	13	5,389	415	2	n.a.	n.a.	251	2.9	0‡‡‡‡	n.a.	3
Karnal	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	174	2.1	350	4.4	11	0.2	3
Amreha	38	n.a.	n.a.	6	n.a.	n.a.	1	28	0.4	57	0.8	0‡‡‡‡	0	2
Bhiwani	16	n.a.	n.a.	5	n.a.	n.a.	3	655	10.6	172	2.8	0‡‡‡‡	0	2
Maunath Bhanjan	37	5,006	135	10	3,630	363	1	n.a.	n.a.	117	2.0	0‡‡‡‡	3.5	3
Hapur	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	80	1.4	250	4.2	.14	4.0	3
Phagwara	14	2,613	187	9	6,202	689	5	32	0.7	271	5.6	26	0.2	1
Modinagar	7	1,810	258	5	3,000	600	1	24	0.7	184	5.1	0‡‡‡‡	1.9	1

Note: Detail may not add to totals due to rounding.
n.a. = not available

** City only
@@@ Partial information, Jagadhri only
**** Data not precisely applicable to city. Enrollment is only for schools reported.
++++ Automatic exchange
‡‡‡‡ No fire protection service in city

Source	
Population (1951 & 1961) Corporate Area (1951 & 1961) Housing Working Force Manufacturing Workers	Census of India 1961, Punjab & Uttar Pradesh, Vols. XIII & XV Part II-A
Employment in Registered Factories	List of Factories Registered in Factory Act List (1948), 1965
Population (1967 - 2nd column) Corporate Area (1967)	Local municipal authorities
Developed Area	Calculated from field notes and existing maps
Power	Field notes based on power supply agencies
Water & Sewerage	Local authorities and state departments of public health engineering
Municipal Roads	Local authorities
Road Tonnage	State regional transport authorities
Rail Sidings & Rail Tonnage	Local railway authorities
Municipal Expenditures & Income Octroi, Toll and Terminal Tax Receipts	Local municipal authorities
Educational Facilities	Local authorities and state educational authorities
Hospitals	State health departments
Telephone Connections	Post & Telegraph Dept.
Fire Protection Garbage & Refuse Disposal Cinemas	Local municipal authorities

and Modinagar at 38 percent. The high working force in Maunath Bhanjan is due to a large female participation ratio in occupations allied to household industry. Census details not included in the City Inventory show that in Maunath Bhanjan, 65.2 percent of the workers are engaged in household industry (primarily hand weaving), of which over 50 percent are female workers. Modinagar provides a different explanation in the sense that it has been developed largely by one entrepreneur as an industrial township, a situation in which the working force proportion in the total population is generally high.

With regard to manufacturing workers* as a percent of the work force, however, cities exhibit far greater differences. Leaving aside Modinagar and Maunath Bhanjan, Table 80 suggests two possible comparison bands: (1) a relatively wide 11 to 30 percent range of manufacturing workers, occurring in two-thirds of the cities studied; and (2) a narrow 36 to 42 percent band where four cities are observed: Kanpur, Ludhiana, Jagadhri-Yamunanagar, and Phagwara. In either case, there is no evidence of disproportionate increases in manufacturing workers as cities increase in size in the 18 city sample.

Density. Corporate area population densities given in Table 80 show the variation over three points of time--1951, 1961, and 1967--the differences in many instances being due more to new territorial annexations to the city than to population changes. The percent of corporate area "developed," however, suggests a more meaningful basis for population density comparisons between cities.† Of the total corporate area, lands actually devoted to urban development vary from 23 percent in Amroha to 84 percent in Gorakhpur.

The population per developed acre is shown both in Table 80 and in Figure 16. Referring to the figure, eight of the 18 cities fall in the mid-range band of densities between 50 and 60 persons persons per acre, with five in the higher 70 to 87 range and five in the lower 23 to 43 range. These variations in population density per developed acre in the 18 cities bear no relation to city size.

Land Use. For the cities where information was available, the City Inventory shows that residential, commercial, and industrial areas average 57 percent of the developed area, with a range of 46 to 68 percent. Open space, public uses, and vacant lands account for the rest. An exception

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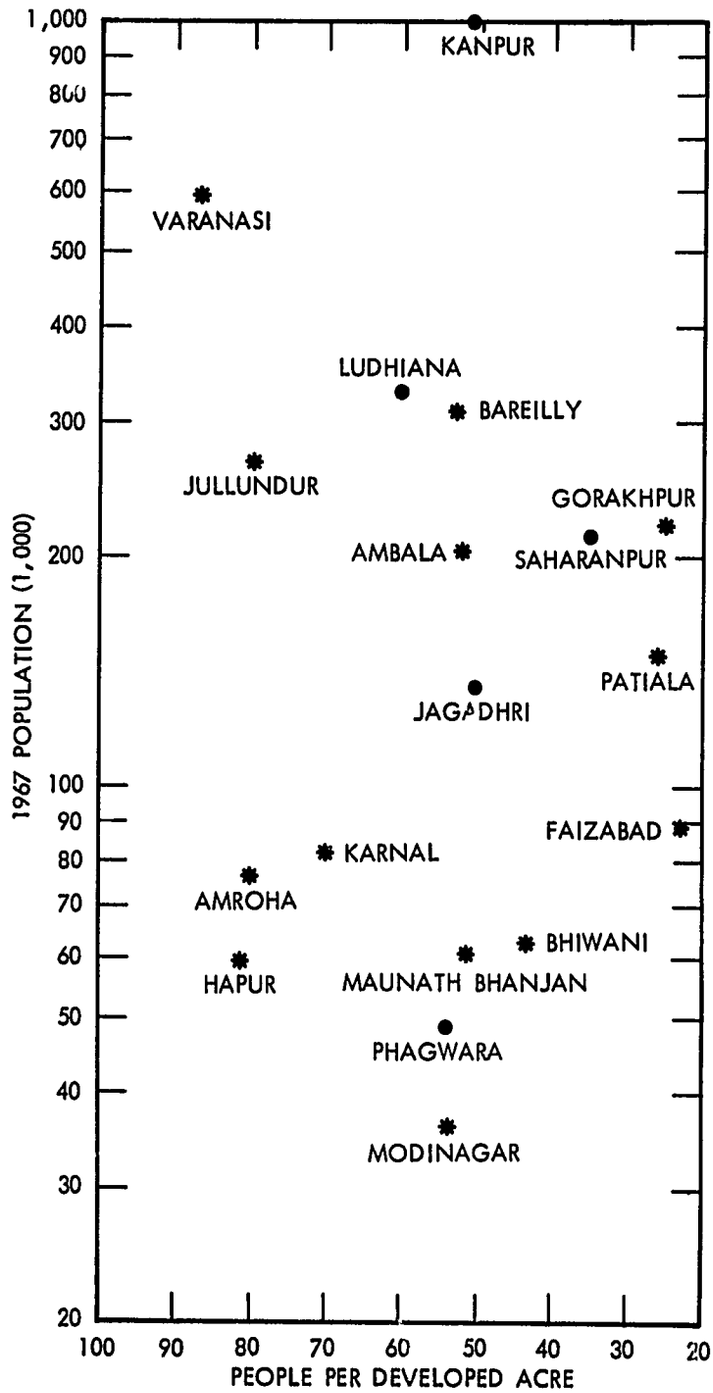
* Manufacturing workers include persons associated with machine production, fabrication, processing, repairs or servicing, and supervision of any one or more of these activities.

† Developed area in this context means the areas that are under urban use and where public utilities and services have been developed. The term includes areas currently vacant but developed with these services.

Figure 16

DEVELOPED AREA DENSITIES, 18 CITIES



is Gorakhpur, where the very high percentage of vacant land in the city's "developed area" may suggest that its urban form and composition are yet to mature. In the case of Kanpur, where one-third of the "developed area" is vacant, considerable infilling with new developments may be possible before more peripheral areas need to develop in response to new growth.

Industrial Infrastructure Characteristics

Power. Availability and use of power distribution capacity in the 18 cities are summarized on the second page of the City Inventory. Perhaps the most striking contrasts here are the sharp differences among cities in per capita consumption of power, whether for industrial or for domestic use.

As would be expected, the six cities with the highest percentage of manufacturing workers are highest also in per capita industrial power consumption. Their range is from 100 kwh per year in Ludhiana to 496 kwh in Phagwara, with an exceptional 1,419 kwh in Modinagar. Four cities have intermediate industrial use from 43 kwh to 89 kwh per capita, the rest falling between 13 kwh and 27 kwh. Domestic power consumption also exhibits distinct levels. Three cities form an upper range from 61 kwh to 95 kwh per capita, six are in a central 25 kwh to 38 kwh range, six are clustered between 14 kwh and 18 kwh, and three consume 9 kwh per capita per year. It can be assumed that these contrasts reflect significant differences in per capita income, extent of household electric supply, and use of household electrical equipment.

Four of the five largest cities are among the five highest in domestic power consumption per capita. Otherwise, no relation is seen between city size and either industrial or domestic per capita power use in the 18 cities.

Power system capacity as defined on the City Inventory refers to distribution capacity, and represents the transformer capacity in million volt amperes of substations serving the city. This may be examined in two ways: with respect to levels of utilization of existing capacity, and from the standpoint of unused or excess capacity available for a potential industrial increment. For the latter purpose, information on the City Inventory must be supplemented by direct field reports from power distribution agencies. These will be taken into account in discussing substation requirements of the five test cities.

As a gross measure of utilization, the system "capacity factor" is shown on Table 80 for those cities in which transformer capacity data were available. For this purpose, the capacity factor is defined as the ratio between the kilowatt hours actually consumed in one year and the kilowatt hours that could have been supplied if the substation facility

had been utilized at full capacity continuously during the whole year.* Because the capacity factor is based on a hypothetical 24-hour supply and does not separately identify the peak load, it can be used as an indicator of overall distribution system utilization but not of available capacity during peak periods.

Different utilization levels are demonstrated by the contrast between Kanpur, Varanasi, and Bareilly, for which capacity factors of 43 to 47 percent were realized in 1966-67, and Phagwara and Modinagar, with capacity factors of 30 to 33 percent. In the latter two cities, the smallest of the study sample, industrial use accounted for 93 to 98 percent of total power consumption. In the former three, industrial use was 44 to 69 percent of total consumption; per capita domestic consumption in Kanpur and Varanasi was somewhat higher than that of Phagwara and more than twice that of Modinagar. It can be inferred that the higher capacity utilization of the three large cities is caused by a higher diversity factor, the load for the larger population and more diversified commercial and service base being more evenly spread over a 24-hour period.

Except for Amroha, which has a relatively low capacity factor of 20 percent, meaningful comparisons of capacity utilization for the remaining cities cannot be made because their substations also provide service to other towns and rural areas, for which separate power consumption data were not available.

Length of city distribution lines is included in Table 80 as a measure of the installed lineal system. The relative stability of low tension line mileage per 1,000 developed acres and per million kilowatt hours consumed in the largest three cities may be noted as an indicator of lineal requirements for relatively complete systems. Distribution line mileage in relation to kwh consumption in the three largest cities is substantially below that in smaller cities, perhaps indicating economies in fixed costs of distribution in the largest cities. No regular pattern for other cities or for mileage per 1,000 persons is observed.

Water. The status of potable water development in the 18 cities is depicted on the second page of the City Inventory. All quantities shown include both domestic and industrial service, since data for making a flowage separation were not available. To this extent, average daily per capita consumption in Kanpur, Jagadhri, and possibly other cities is influenced by atypical industrial water demands. In all cases but one, the cities share the benefits of the vast underground water resources of

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* For an analogous definition and application of the capacity factor to total system supply, based on installed generating capacity, see Economic Aspects of Electric Power Production in Selected Countries, U.S. Agency for International Development, Washington, D.C., July 1955, pp. 4 and 25 and Appendix C.

the Gangetic plain. The two largest cities use river water also; however, per capita consumption for these is no higher than for some of the smaller cities which rely solely on underground water. Bhiwani is served by a nearby canal; underground sources for city water supply have not been tapped.

Wide disparities in the stage of system development and the consumption level of water may be seen from Table 80. Both are random from the standpoint of city size, with the possible exception that the two largest cities both have water systems that are reported to serve the entire corporate population and are among the highest in consumption per person served. Few cities, including the largest, have totally integrated city-wide water systems. Rather there are numerous small and isolated tubewell and distribution systems, making it difficult to relate levels of consumption with city size or the stage of system completion. Moreover, in no city was there a systematic flowage measuring program to record water usage on a total basis. Similarly, the lack of metering at the source meant that pump "name plate" data many times provided the only indication of system capacity. The "Available Capacity" data shown in the City Inventory are best-judgment figures based on well and pump efficiency, age, and reasonable operating times.

Relative to capacity, the surpluses available as shown in Table 80 are random with respect to city size. In seven cities, 40 percent or more of available capacity is reported as surplus. Six of these cities have among the lowest water consumption per person served, and five are among the highest in length of installed water mains per million gallons consumed. These six cities, ranging in population from 48,000 to 304,000, illustrate the stage of extension of water systems to neighborhoods whose full consumption pattern has yet to materialize. Their surpluses, however, exist largely in particular neighborhood networks and do not reflect a surplus for the city as a whole. From the standpoint of major new industrial demands, they are therefore for the most part theoretical.

Accordingly, it is appropriate to assume that substantial new industrial increments cannot be accommodated by the existing water systems, except perhaps for individual cities or particular locales.

Sewerage. Because of the very minimal development that has occurred in regard to sanitary sewage collection facilities, little comparable data can be assembled. The last column on the second page of the City Inventory illustrates this substandard condition. By and large, the stage of sanitary sewer development can be described as follows: Of the 18 cities studied, 11 have partially completed systems covering either several pockets within the city or partial development of a total city system. Varanasi is an exception, with a fully completed system. Six cities--Ambala, Faizabad, Amroha, Bhiwani, Maunath Bhanjan, and Modinagar--have no city sewerage system, except inadequate open drains. Lack of sewerage is thus to some extent associated with smaller cities. Although Ambala's estimated population in 1967 was 202,000, the other cities without sewerage were all below 100,000 population.

In all cities, except Varanasi, development of underground sewerage is in its early stages. The proposals are mainly for buried ring sewers to collect sewage from several nodal points in the city through open drains. Disposal of sewage is without treatment either to an existing river or creek, or for irrigation. Because most of the new proposals for city sewerage systems are at different stages of development and completion, little meaningful analysis can be made as to this facility.

Roads. In considering the amount of paved municipal roads in each of the 18 cities, comparisons have been expressed in several ways in the City Inventory. To illustrate one comparison, road density (miles per unit area) is shown related to the developed area. Eighty-eight percent of the cities contained between 10 and 25 miles of paved roadway for every 1,000 acres of developed land. This is too broad a range to bear much significance; however, there is no apparent efficiency in road miles as the size of developed area increases. This means that the total municipal road network is little affected by interneighborhood connections and that intraneighborhood mileage per acre is more or less the same for the very largest city as for the smallest. This, of course, supports the generally accepted view that road density is primarily a function of traffic demand, and lot and block design.

Information on road tonnage in Table 80 pertains to intercity shipments, data on intracity tonnage being unavailable. The wide variations in tonnage per road mile are accordingly related more to the location of cities on regional road networks than to size of city.

Capacity Available for Industry. To summarize, our quantitative review of urban facilities directly used by industry--power, water, sewerage, roads--does not reveal any general availability of unused capacity in quantities needed for significant industrial expansion. In the few cases where relatively substantial excess capacity appears to exist among the 18 cities, this is not consistently applicable to all facilities and has no systematic relation to city size. Utilization of such unused capacity would in most cases depend on local confirmation of availability for the particular site and periods required by new industrial entrants.

Municipal Income and Expenditure

The City Inventory gives the municipal income and expenditure which indirectly measure the city's economic well being and indicate the awareness of the local authorities toward sustaining the civic services. Three distinct levels of municipal income and expenditure per capita are observed from Table 80. For the population range 100,000-500,000, per capita municipal income and expenditure are between Rs. 15 and Rs. 22, while for cities below 100,000, the per capita figures decline to a range of Rs. 12 to Rs. 15. Exceptions to these ranges are Faizabad, Hapur, and Modinagar. Faizabad and Hapur show a higher order of income and expenditure because

they levy special license fees in connection with religious fairs and wholesale grain trading. Modinagar is administered by a notified area committee, as distinct from a municipal board, and has limited taxation powers. Kanpur, being a corporation, has high per capita income and expenditure. The ranges shown indicate that there is a tendency for municipal income and expenditure to vary with the size of the city.

Octroi, terminal, and toll taxes form a major portion of municipal incomes. Except Kanpur, where the local authority has other important sources of income, all other municipalities rely heavily on this source. This in a way shows the inelasticity of the tax structure of the local bodies in the field region.

Index of Development and Selection of Test Cities

The City Inventory suggests that there may be many more possibilities for comparison. Unfortunately, this is not necessarily the case. These are developing cities, and in their process of developing they present a continual and varied imbalance between demand for public facilities or services and ability to provide. Where a balance can be found in a few individual facilities or services, it often ceases to exist when a new wave of population growth occurs, or standards change, or relatively sudden, new industrial demands are placed upon the system. In countries where complete complements of facilities and services exist in most cities, added increments of industry may well present reconcilable incremental requirements upon those public facilities. In developing countries, however, the addition of new industry increments usually serves only to exaggerate an already existing and overtaxed increment of public facility need that is currently unsatisfied--an existing increment that varies not only city by city but also facility by facility.

These prefacing remarks show the difficulty of attempting a quantitative summation of relative overall levels of facility development in the 18 cities. The need for such a baseline or datum for comparative study, however, was recognized from the earliest phases of field research. Such a comparison measure is specifically needed to guide selection of representative test cities for which cost estimates are to be worked out in detail. A comparative Index of Development has therefore been constructed and is presented in Table 81 with related developmental indicators.

The central feature of the Index of Development is a set of normalized or percentage measures of development levels in each city for power, water, sanitation, roads, and telephone service, each on a scale of 1 to 100. The totals for each city given in the extreme right column of Table 81 are the Index numbers used for comparing overall levels of present facility development. A city theoretically achieving the maximum Index number of 500 would have (1) a fully developed water supply and distribution system serving its total population; (2) a citywide piped sanitary collection and disposal system (without, however, sludge digestion or chemical treatment of effluent); (3) the highest per capita consumption

Table 81

SELECTED FACTORS FOR 18 INDIAN CITIES

City	Estimated Corporate Population 1967 (no.)	Persons Per Developed Acre 1967 (no.)	Persons Per Occupied Residential House 1961 (no.)	Indexes* Ten Year Population Growth Rate 1951-1961 (Jagadhri-Yamunanagar 113 = 100)	Indexes* Manufacturing Workers as % of Total Work Force 1961 (Modinagar 72 = 100)	Indexes* Industrial Power Consumption as % of Total 1966-67 (Modinagar 86 = 100)	Index of Development* 1966-67: Domestic Power Consumption KWH Per Capita (Jullundur 95 = 100)	Index of Development* 1966-67: Percentage of Corporate Population Served by Water Supply (%)	Index of Development* 1966-67: Percentage of City Sewerage System Completed (%)	Index of Development* 1966-67: Paved Municipal Roads Per 1,000 Acres of Developed Area, Miles (Hapur 41 = 100)	Index of Development* 1966-67: Telephone Connections Per 1,000 Persons (Jullundur 15 = 100)	Tota (Inde
Kanpur	1,070	50†	6.0	35	50	70	40	100	68	37	58	303
Varanasi	573	87‡	9.7	34	17	48	39	100	100	39	44	322
Ludhiana	323	60†	5.2	52	50	60	64	67	25	32	45	233
Bareilly	304	53	7.6	30	32	45	15	82	31	62	32	222
Jullundur	266	80†	5.5	28	38	46	100	60	72	75	100	407
Gorakhpur	216	25§	5.6	32	24	39	9	100	27	42	30	208
Saharanpur	212	35**	6.1	22	38	47	26	61	46	55††	28	216
Ambala (Town Group)	202	52†‡‡	5.2	18	18	38	19	77	0	55††	56	207
Patiala	145	26	5.1	25	19	64	35	72	5	26	46	184
Jagadhri-Yamunanagar	132	50	4.9	100	58	73	17	54	12	24	41	148
Faizabad	88	23	5.3	8	15	41	35	100	0	57	19	211
Karnal	81	70	5.1	19	21	16	87	83	74	64	30	338
Amroha	76	80	7.1	15	26	61	10	99	0	29	5	143
Bhiwani	62	43	5.2	11	42	90	15	100	0	38	19	172
Maunath Bhanjan	60	51	7.1	35	4	n.a.	9	50	0	59	13	131
Hapur	59	81§§	6.2	11	17	n.a.	16	100	20	100	28	264
Phagwara	48	54‡	5.4	42	54	95	34	8	57	50	38	187
Modinagar	36	54†	4.4	86	100	100	18	85††	0	48	34	185

n.a. = not available

* Indexes are based on percentage to city with highest data.
† 1963
‡ 1965
§ 1964
** 1962
†† Estimated
‡‡ City only
§§ 1966

Source: Based on City Inventory, Table 80.

of electric power compared to all other cities; (4) the most telephone connections per capita; and (5) a higher percentage of roads in its developed area than all others. Conversely, if it were possible for a city to exist with a zero rating, it would have no formal or systematic communal type facilities whatsoever.

It is logical to consider whether an Index giving greater weight to one or more of these or other facilities, regarded in some sense as more basic, would be more satisfactory as a measure of development. This would be the case, for example, in planning for a set of industries that is particularly intensive in certain infrastructure requirements, such as power or transport. In testing the cost hypothesis, however, conclusions of more general relevance can be gained by considering the ability of cities to meet requirements of a more diverse set of industries. As indicated in the previous chapter, a composite mix of industries corresponds to the apparent potential of medium size cities in the 100,000 to 250,000 population range in the study region. Such industries offer a representative and meaningful test of the hypothesis. For diversified industries, reasonably balanced urban facilities are required. It was concluded, therefore, that an Index of Development giving equal weight to each facility needed by representative industries would be most valid.

The Index of Development shows a reasonably clear tendency of greater facility development with increase in city size. The tendency is more stable for cities of 200,000 population and over, coincidentally starting with Index levels of 207-216 for cities of 202,000 to 216,000. A progressive increase to the 303-322 range for the largest two cities is observed, broken by the exceptionally high 407 for Jullundur. Below 200,000 population, the central Index range is 172-187, achieved by four cities of varying population. Three cities show significantly higher Index values above this range and three have much lower values. Among the latter, the low 148 figure for Jagadhri is largely attributable to the city's exceptional rate of population increase, with which facility development has not been able to keep pace.

The first criterion established in selecting cities for developmental cost estimation was that insofar as possible, they should be representative of their population size classes with respect to the Index of Development.

A second factor taken into account in selecting test cities was urban density, for its influence both on site availability and on requirements and costs of incremental facilities. It was seen above in reviewing the City Inventory that density in the 13 cities, measured by persons per developed acre, is unrelated to city size. This absence of correlation makes it logical to conduct the cost test in a manner that holds density constant, by selecting test cities that are in the same density range and by keeping the density of new development areas constant as a basis for cost estimation. The central density range of 50 to 60 persons per developed acre, which includes nearly half the 18 cities, is most representative for the choice of test cities. Four of the five cities chosen are within this range.

In addition, density is expressed in Table 81 in terms of persons per house. A better measure--persons per built-up area--was not obtainable because of inadequacy of existing land use data in the cities studied. Desiring some comparability between city sizes in regard to housing development, the persons per house figures provide at least one indication. Density in these terms varies from 9.7 people per occupied house in Varanasi to 4.4 people in Modinagar, but densities of about 5 to 6 persons per house prevail in 13 of the 18 cities. The selected test cities fall in this latter range.

The final consideration in the choice of test cities related to pressure of demand upon or rate of utilization of existing facilities. It was felt desirable for comparative purposes to choose cities as similar as possible in this regard. Since overall demand is influenced strongly by the city growth rate and intensity of manufacturing activity, measures of these factors on Table 81 were examined as indicators of levels of demand.

Because manufacturing potential was stressed among the criteria that resulted in the original selection of 18 cities, no weight was given to this factor in selecting the five test cities. Only a screening criterion was applied, excluding cities which the field survey showed to be low in present manufacturing potential or in which manufacturing forms almost the total economic activity.

Combining the above criteria, the cities selected for costing of incremental infrastructure for industry are:

	City	1967 Population
A	Phagwara	48,000
B	Jagadhri-Yamunanagar	132,000
C	Saharanpur	212,000
D	Ludhiana	323,000
E	Kanpur	1,070,000

Apart from Jagadhri-Yamunanagar, for which land use data were not available, the test cities fall within a reasonably close range with regard to the share of developed area in residential, commercial, and industrial uses: Phagwara 59 percent, Saharanpur 51 percent, Ludhiana 57 percent, and Kanpur 46 percent.

Construction Costs and City Size

The degree to which economic conditions associated with city size influence costs of construction is obviously a significant question for this study. City size is a direct determinant of the size of a city's construction industry, which in turn may influence levels of productivity and management efficiency. Without special studies on productivity and data on rates of return, such effects are difficult to detect or evaluate. Economic factors related to city size may also affect levels of wages in the construction trades and prices of building materials. These can be measured directly.

In order to test possible effects of city size on the costs of construction inputs, multiple regression analyses on city population were carried out for the six building material prices and three construction wages reported in Appendix A, for 1961, 1966, and 1967. The multiple regression is not significant for any year.

Bivariate correlation coefficients between individual construction inputs and city size and between each pair of inputs, shown on Table 82, are for the most part very low. Paired wage rates have significant bivariate correlations, stronger for 1961 than for 1966 or 1967, but wages are not significantly correlated with city size. Only two building material prices, steel and aggregate, are significantly correlated with city size. Steel bars and rods show significant negative correlations with city size, increasing from -.42 in 1961 to -.56 in 1966 and -.62 in 1967.* The price of stone aggregate displays the reverse case, being higher in large cities with a consistent bivariate correlation, significant at the 5 percent level in 1961. The prices of sand and aggregate are positively correlated (r = .53, .42, and .37 in the three years, respectively) but sand prices show no correlation with city size. Substantial negative correlations between stone aggregate prices and the three building trade rates reflect the distant sources and high costs of aggregate in eastern Uttar Pradesh, a regional cost influence.

In short, the cumulative effect of price relationships and movements among all nine elements has no evident relationship with city size.

A second test of possible city size influences on construction costs was made by using the weighted incidence of material and labor prices in total construction costs and the wider list of material prices and labor wages built into the road and overhead water tank cost indexes. These two indexes together with the general construction index (based on industrial housing) are plotted for the 18 cities in Figure 17. The wide scatter of costs is evident, obviously reflecting local influence as well as regional factors. The spread in road costs is most pronounced, again reflecting the high cost of stone aggregate in the eastern part of the study region.

It is concluded that costs of construction inputs do not differ systematically as a function of city size in the 18 cities studied. Accordingly, in estimating costs for the five test cities, no cost adjustment for city size is introduced.

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* Higher costs of steel bars and rods in smaller cities may be explained in part by transport costs from major distribution and stockists' centers, in part by smaller requirements and less competitive suppliers in smaller centers, and possibly in part by effects of the allocation system.

Table 82

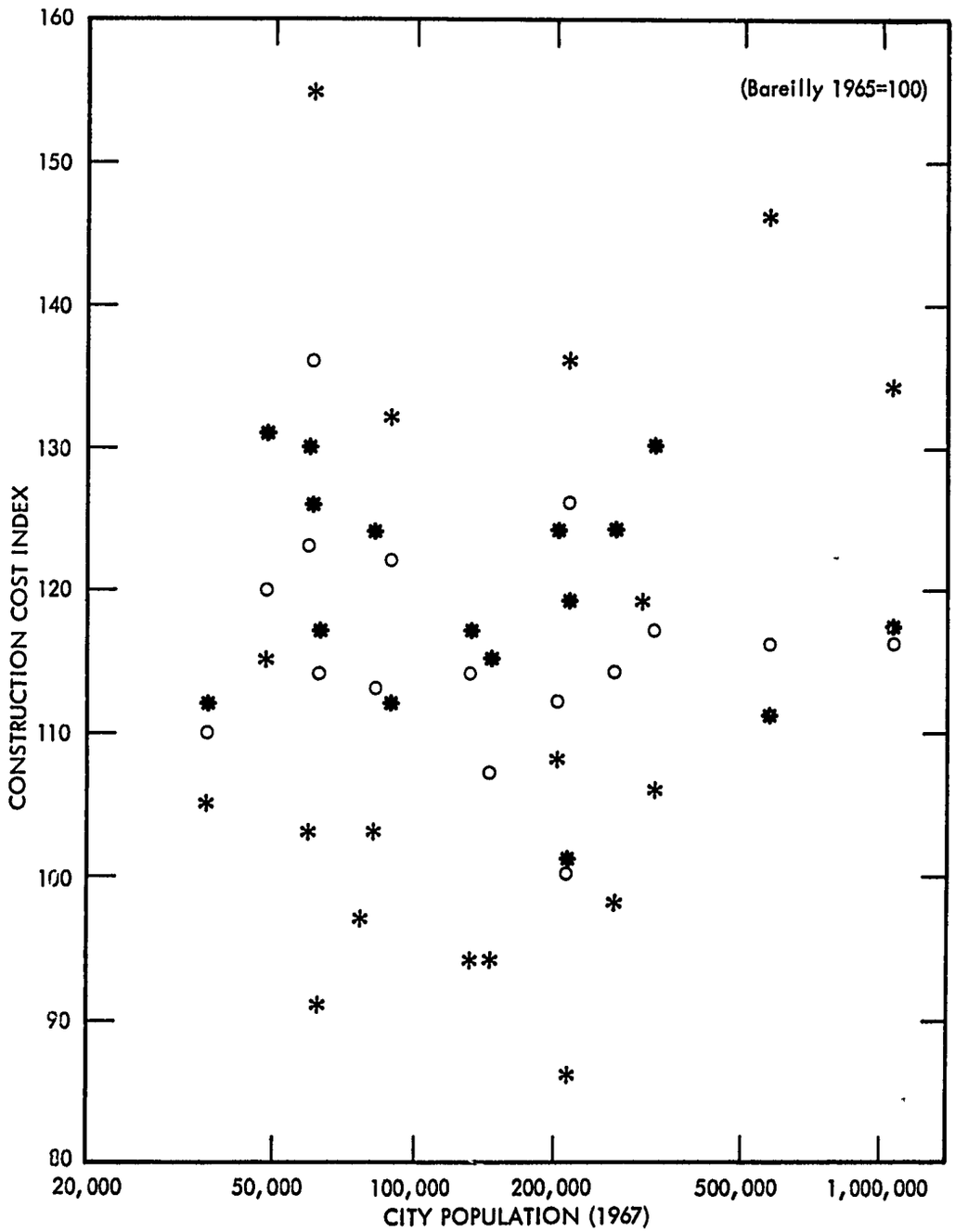
BIVARIATE CORRELATION COEFFICIENTS,
CITY POPULATION, BUILDING MATERIAL PRICES, AND CONSTRUCTION WAGES
18 Cities

	Population	Brick	Cement	Sand	Aggregate	Steel	Timber	Mason	Carpenter	Unskilled Laborer
				1962 Prices						
1961 population	-1.00	0.03	0.10	-0.01	0.40*	-0.42*	-0.15	-0.14	-0.05	-0.19
Brick	0.03	1.00	0.24	0.05	-0.30	0.08	0.23	-0.15	-0.44*	0.12
Cement	-0.10	0.24	1.00	0.22	0.16	-0.17	0.35	-0.01	0.04	0.00
Sand	-0.01	0.05	0.22	1.00	0.53*	0.27	-0.32	-0.40	-0.43*	-0.54*
Aggregate	0.40*	-0.30	0.16	0.53*	1.00	0.04	-0.43*	-0.43*	-0.27	-0.47*
Steel	-0.42*	0.08	-0.17	0.27	0.04	1.00	-0.31	-0.20	-0 20	-0.14
Timber	-0.15	0.23	0.35	-0.32	-0.43*	-0.31	1.00	0.25	0.22	0.33
Mason	-0.14	-0 15	-0.01	-0.40	-0.43*	-0.20	0.25	1.00	0.91†	0.90†
Carpenter	-0.05	-0.44*	0.04	-0.43	-0.27	-0.20	0.22	0.91†	1.00	0.76†
Unskilled laborer	-0.19	0.12	0.00	-0.54*	-0.47*	-0.14	0.33	0.90†	0.76†	1.00
				1967 Prices						
1967 population (est.)	1.00	0.18	-0.27	-0.14	0.32	-0.62†	-0.16	-0.20	-0.09	-0.14
Brick	0.18	1.00	-0.17	0.27	0.16	0.09	0.03	-0.30	-0.26	0.24
Cement	-0.27	-0.17	1.00	0.03	0.17	0.06	0.41*	0.20	-0.12	0.06
Sand	-0.14	0.27	0.03	1.00	0.37	0.36	-0.35	-0.18	-0.27	-0.17
Aggregate	0.32	0.16	0.17	0.37	1.00	-0.04	-0.41*	-0.53*	-0.36	-0.35
Steel	-0.62†	0.09	0.06	0.36	-0.04	1.00	-0.13	-0 11	-0.02	0.08
Timber	-0.16	0.03	0.41*	-0 35	-0.41*	-0.13	1.00	0.28	0.26	0.31
Mason	-0.20	-0.30	0.20	-0.18	-0.53*	-0.11	0.28	1.00	0.63†	0.65†
Carpenter	-0.09	-0.26	-0.12	-0.27	-0.36	-0.02	0.26	0.63†	1.00	0.57†
Unskilled laborer	-0.14	0.24	0.06	-0.17	-0.35	0.08	0.31	0.65†	0.57†	1.00

* Significant at the 5 percent level.
† Significant at the 1 percent level.

Figure 17

CONSTRUCTION COST INDEXES AND CITY SIZE, 18 CITIES, 1967



✱ INDUSTRIAL HOUSING
o OVERHEAD WATER TANKS
* BITUMEN ROADS

Potential Size and Composition of Industry Mixes

The starting point for determining industry mixes for different size cities is provided in Table 79. The table, in giving orientation of industries to different city sizes, premises that each city size in its hierarchical order has certain functions which in association with other factors shape the industrial composition, growth structure, and linkages. For cities that are favorably situated and otherwise oriented to industrial growth, it is considered that such functional relationships within the study region enable middle size cities in the population range of 100,000-250,000 to support sufficient complementary industries to foster emergence of external economies. Below this range, industrial growth rests upon greater resource use in combination with the minimum or ubiquitous industrial category. Above about 250,000 population, specialization and agglomeration economies interplay to provide acceleration effects resulting in overall industrial development.

We take the median test city, 212,000, as the basis for constituting an industrial mix that is representative for the region, offering interfirm and interindustry linkages that make for external or joint economies. The mix is built up in two steps. List A* industries are first provided for, comprising those industries that can be expected to expand in all size cities. To these are added industries of List C, having in mind potential linkages to those on List A as well as concurrent growth of similar labor skills and specialized subcontracting services. This provides the "composition" of a median mix.

The question of determining the size of mix in terms of value added for median and other size cities is examined from two angles:

1. Determining the share of each size city in the total envisaged volume of increased manufacturing activity, in a 10-year period.

2. Selecting plant size for each product line constituting the mix.

The volume of increased manufacturing activity to be taken as the basis for determining infrastructure needs in five test cities of different size was estimated through the following steps and assumptions:

1. Value added by manufacture in the five cities in 1965 was estimated by multiplying factory employment in each industry in each city by national value added per employee in the given industry. Value added in the five cities as estimated by this method was Rs. 155,844,000, exclusive of major industries not included in the prospective incremental mix such as sugar, pulp and paper, cigarettes, rayon, cotton and woolen fabrics, and heavy engineering. The aggregate figure, Rs. 155,844,000, was taken as the base for projecting 10-year growth of the prospective industry increment.

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* Lists A, B, C, and D industries in this section refer to those detailed in Table 79.

2. Appendix C, Table C-1, gives an estimate of projected growth in industries of the types included in incremental mixes, leading to a weighted average projected increase of 247 percent for a 10-year period.* Value added by manufacture as determined in the previous step was increased by 247 percent to obtain the total projected increment for five cities. The first increment of output is taken to be accomplished by better use of existing plant capacity. Average capacity utilization of existing plants is assumed to improve from 50 percent to 80 percent, an average increase of 60 percent. The increment to be produced by new or expanded factories is 187 percent. Computations for these three steps are as follows:

   a. Total projected increment for five cities:
      Rs. 155,844,000 x 247 percent = Rs. 384,935,000

   b. Assumed share of existing factories:
      Rs. 155,844,000 x 60 percent = Rs. 93,506,000

   c. Increment for new or expanded factories:
      Rs. 155,844,000 x 187 percent = Rs. 291,429,000

3. In defining the size of industrial mixes for the five cities, it was necessary to examine the practical meaning of "holding other things constant" for a test of the cost hypothesis. A constant size of mix would make little practical sense in comparing cities which differ twenty-fold in population size Alternatively, projection of urban industrial growth rates would, at a minimum, require a "multiplier" analysis based on strong assumptions and data for which little evidence exists in the study region or in developing countries generally. Instead of complicated assumptions, common sense suggested that industry magnitudes proportionate to some measure of city size would offer a more clearcut test. In order to relate the size of mix to existing manufacturing activity, manufacturing employment in the five cities as of 1961 was taken instead of population as the measure of city size for this purpose. Total incremental value added, Rs. 384,935,000, was divided in proportion to the distribution of manufacturing employment in the five cities, to give estimates of increases in value added for existing and new or expanded factories. These estimates are summarized in Table 83.

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* Mr. S. Balakrishna, of the Indian Advisory Committee, comments on the basis of studies completed by the National Council of Applied Economic Research that this growth rate for industry is high. In estimating growth in the chosen industries, we have relied on the official projections of material and financial balances available (see Appendix C, Table C-1), and have made no independent estimates of industrial growth. For the effects of a lower industrial growth rate on the cost estimates, see Chapter VI.

Table 83

ESTIMATES OF INCREMENTAL VALUE ADDED
IN EXISTING AND NEW OR EXPANDED FACTORIES, BY CITY SIZE

	City Population 1967	Manufacturing Employment 1961		Share of Increment in Value Added	
		Persons	Percent	Existing Factories (Rs. 000)	New or Expanded Factories (Rs. 000)
A	48,000	4,066	2.55%	2,380	7,430
B	132,000	11,298	7.09	6,630	20,660
C	212,000	14,706	9.22	8,620	26,870
D	323,000	26,081	16.36	15,300	47,670
E	1,070,000	103,301	64.78	60,570	188,770
		159,452	100.00%	93,500	291,400

Plant sizes for individual industries were identified from among the interviewed firms, on the criterion of viability. Viability was judged, in a qualitative sense, from overall performance and efficiency of the firms. Production levels of selected firms were assigned to individual industries constituting the mix for the "median city." Infrastructure coefficients were then applied to the production levels to arrive at gross requirements of the median mix. The gap between the aggregate production of median mix industries converted into value added, and the incremental value added as indicated in Table 84, is termed as "unspecified," representing industries whose types were of indeterminate nature. Infrastructure requirements of the unspecified group were adjusted on the basis of the average coefficients of Lists A and C, per unit of Rs. 1,000 value added. The resulting "median mix" with corresponding infrastructure requirements is presented in Table 84.

Table 84

ILLUSTRATIVE MEDIAN MIX COMPOSITION AND REQUIREMENTS

Indian Code No.	Industry Title	Plants (no.)	Prod (Rs 000)	Value Added (Rs 000)	Employees (no.)	Floor Space (000 sq ft)	Storage Space (000 sq ft)	Connected Load (kw)	Power Consumption (000 kwh)	Water Consumption (gpd)	Tonnage Road (tons)	Tonnage Rail (tons)	Tonnage Total (tons)
	Ubiquitous or Core Industries												
205-1	Flour mills	1	7,206	384 9	43	30	3	166	833	22,890	6,158	12,393	18,591
206	Bakery products	1	1,358	391 1	80	21	2	36	32	1,983	219	950	1,169
209-2a	Edible oils-oil expellers*	1	9,000	396 0	99	27	22	169	508	12,060	7,742	4,411	12,153
231-1	Cotton textiles-power looms*	2	1,000	262 0	78	11	negl.	32	78	390	859	621	1,480
231-7a	Textile finishing & processing-single process+	1	310	85 3	92	11	1	82	120	11,577	707	479	1,186
260-2	Metal furniture & fixtures	1	453	110 0	32	2	negl.	8	11	83	136	32	168
313	Paints varnishes & lacquers	1	1,238	355 3	39	10	1	64	23	227	142	458	600
319-2	Insecticides fungicides & weedicides	1	1,273	257 6	39	5	2	37	158	67	956	319	1,275
339-2	Pipe pipes & other cement & concrete products	1	1,001	353 3	83	8	n.a.	30	35	5,610	19,675	4,243	23,918
341-5b	Cast iron pipes	1	1,110	322 6	251	50	10	35	35	1,600	1,197	3,355	4,552
350-1b	Utensils	2	681	153 9	68	17	7	64	81	1,033	197	299	496
350-10a	Hand tools	1	1,602	690.5	147	27	11	151	30	293	511	1,056	1,567
350-12	Sanitary & plumbing fixtures	1	915	217 1	109	6	1	36	41	1,633	27	27	54
350-13	Weights	1	2,082	597 5	161	18	2	39	66	2,067	2,463	3,017	5,180
360-5 11	Power driven pumps	1	1,194	374 9	85	15	2	36	32	4,973	412	596	1,008
360-8 2a	Harrows, cultivators & plows	1	360	212 9	45	7	4	17	25	130	1,103	304	1,407
360-8 2b	Chaff threshers	1	960	242 9	86	14	2	36	34	57	831	80	911
360-8 2d	Hand pumps	1	439	141.1	59	14	3	16	28	117	267	655	922
370-1	Electrical equipment	1	1 211	327 0	121	10	3	30	39	1,067	350	36	386
399-7	Plastic moulded goods	2	400	102 8	20	3	1	28	50	1 763	61	11	72
	Subtotal	23	31,758	6,035 7	1,740	306	77	1,132	2,259	72,650	43,753	33,342	77,095
	Industries Oriented to Medium Cities												
203a	Dehydrated fruits & vegetables	1	4,800	1,022 4	566	22	22	82	393	95,999	5,950	286	6,236
209-2b	Edible oils-solvent extraction*	1	4 865	2,9 1	83	28	26	112	254	14 993	5,617	7,473	13,090
232	Knitting mill woolen hosiery	1	5,200	1,1[illegible]0 1	291	14	15	26	53	397	1,162	3,222	7,684
271-5	Paper for packaging	1	480	88 3	[illegible]	3	1	35	52	113	38	120	158
300-3	Rubber footwear	1	1,762	717 1	103	10	2	90	151	67,763	1,778	265	2,013
3[illegible]-5	[illegible] pharmaceuticals	1	800	151 2	71	12	3	13	19	790	14	113	127
341-1a	Iron & steel rerolling	1	2,915	737 5	88	24	7	367	642	24,483	2,972	5 222	8,194
341-5a	Conduit pipes	1	180	107 5	61	16	6	13	23	153	225	358	583
350-3	Felt nut & bolts screws, etc	1	1,100	351 1	76	20	4	48	80	3,617	643	1 627	2 270
350-10b	Small [illegible] cutting tools	1	960	113 7	105	7	2	90	58	157	n a	n a	n a
360-3	[illegible] combustion engines	1	2,397	978 0	266	81	10	101	98	12,307	284	1,663	1,917
360-1 1	[illegible]	1	17,502	7,350 8	1,688	279	103	889	1,492	58 560	11 819	31,990	19 839
360-5 2	[illegible]	1	915	285 5	120	14	3	82	50	237	271	305	576
360-7	[illegible] machine tools	1	1,100	532 0	200	35	25	138	95	1,250	1 277	1 484	2,761
360-8 2c	Dusters sprayers	1	150	113 9	56	2	n.a.	15	6	230	n a	n a	n a
360-8 2f	Chaff cutters & spare parts	1	1,626	312 2	125	22	12	65	62	9 377	954	2 863	3 821
360-11 5a	Cleaning washing machines	1	2,315	811 1	196	49	1	150	179	3,503	2 653	1,104	3,757
360-11 6	Non electric household equipment	1	110	110 0	62	7	3	15	25	207	97	739	836
370-1 1a	Switchgears	1	2 394	616 1	285	45	6	74	70	1,[illegible]	1 325	621	1 916
370-1 1b	[illegible]	1	399	107 7	40	2	1	13	9	[illegible]	151	22	173
370-1 2	Electricity meters	1	1,283	383 7	136	7	1	42	41	273	21	39	63
370-1 10	[illegible] batteries	1	288	109 7	88	4	2	79	129	177	337	[illegible]	337
385	[illegible]	1	3 031	700 9	93	19	n a	105	40	12 0 3	2 276	04	2 580
389a	Auto parts	1	1,696	255 4	153	22	13	70	71	3,000	230	536	766
389b	Bicycle	1	1,120	261 0	32	4	1	22	40	393	204	0	204
391-3a	Scientific instruments	1	2 257	1,169 1	269	50	6	119	79	1 020	70	175	245
391-1	Mathematical, surveying & drawing instruments	1	480	272 2	140	9	2	14	13	280	11	3	14
	Subtotal	27	63,108	19,524 5	4,759	837	277	2,899	4,224	312,998	46 716	63,534	110,280
	Total	50	97,866	25,560 2	6,499	1,143	354	4,031	6,483	385,648	90,499	96,876	187,375
	Raised to 26,870,000 value added (105.12%)	51	102,877	26,870.0	6,832	1,202	372	4,237	6,815	405,426	95,133	101,836	196,969

n a = not available
negl. = negligible, less than 500 sq ft

* Three shift operation
† Two shift operation

The median mix represents a somewhat advanced degree of diversification for a middle size city capable of rapid industrial expansion. Because of its diversified nature, the median mix presents a representative bill of infrastructure requirements achieved by balancing of high use of certain infrastructure facilities with low use of others. It is instructive to examine the coefficients of requirements separately for List A industries in the median mix with those of List C These are given in Table 85.

Table 85 shows that infrastructure requirements of ubiquitous industries for adding Rs. 1,000 value by manufacture are somewhat greater than than those of medium city oriented industries. The difference is most pronounced in transport requirements--12.77 tons per Rs. 1,000 value added for ubiquitous industries compared with 5.64 tons for industries oriented to medium cities. Road transport requirements increase more steeply than rail tonnage for the ubiquitous industry mix. Both the overall greater tonnage and its orientation to road transport are consistent with the high transport content and local market orientation which characterize ubiquitous industries.*

Industry mixes for other size cities were developed through two separate procedures to meet two kinds of tests of the cost hypothesis. The first test is concerned with a situation where the proportion of requirements for each infrastructure element is constant among the five test cities. The purpose here is to provide a clearcut test of the effects of city size, with other factors held constant. This test is carried out by directly varying the size of the median mix, and hence its infrastructure requirements, in proportion to incremental value added in the five test cities. Because of its diversified character, the median mix is taken as an appropriate determinant of infrastructure needs to be costed out for the five cities. The resulting requirements are summarized in Table 86. Since the incremental infrastructure requirements are proportionate or homogeneous functions of incremental value added in the five cities, we well refer to the first cost test, based on Table 86, as the test for a "proportionate change in industries," or, simply, for "the proportionate mix."

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* Table 85, showing the contrasts in the physical input requirements of ubiquitous and medium city oriented industries, also supports the observation that with greater diversification, which is manifest in List C industries, value of product by manufacture can be added with lower physical inputs. In this sense, List C may represent a higher level of technological association, compared with the List A constituent of the median industry mix. Coefficients of infrastructure for List D industries shown in a subsequent table fall between ubiquitous and medium city industry requirements, obviously because of the specialized category of industries included to represent the large city oriented group.

Table 85

INFRASTRUCTURE DEMANDS OF UBIQUITOUS AND MEDIUM CITY INDUSTRY MIXES
(Coefficients per Rs. 1,000 Value Added)

Infrastructure	Ubiquitous	Medium City	Median City (ubiquitous and medium)
Employment	.288	.244	.254
Floor space (sq ft)	51	43	45
Storage space (sq ft)	13	14	14
Connected load (kw)	.188	.148	.158
Power consumption (kwh)	374	216	254
Water consumption (gpd)	12	16	15
Transport			
Road (tons)	7.25	2.39	3.54
Rail (tons)	5.52	3.25	3.79
Total (tons)	12.77	5.64	7.33

Table 86

ESTIMATED INCREASE IN INFRASTRUCTURE REQUIREMENTS WITH PROPORTIONATE INDUSTRIAL INCREMENTS IN CITIES OF FIVE SIZE CATEGORIES

	Estimated Increments				
	A	B	C	D	E
City population (1967)	48,000	132,000	212,000	323,000	1,070,000
Existing factories					
Value added* (Rs. 000)	2,380	6,630	8,620	15,300	60,570
Power consumption* (000 kwh)	605	1,685	2,190	3,885	15,385
Transport*					
Road (tons)	8,430	23,500	30,500	54,200	214,000
Rail (tons)	9,020	25,100	32,700	58,000	230,000
Water consumption (gpd)	36,000	100,000	130,000	231,000	915,000
New or expanded factories					
Value added* (Rs. 000)	7,430	20,660	26,870	47,670	188,770
Employees (no.)	1,890	5,250	6,830	12,100	47,900
Floor space (000 sq ft)	334	930	1,200	2,150	8,490
Storage space (000 sq ft)	104	290	370	670	2,640
Connected load (kw)	1,170	3,260	4,240	7,530	29,800
Power consumption* (000 kwh)	1,800	5,240	6,815	12,130	47,910
Transport*					
Road (tons)	26,300	73,100	95,100	169,000	668,000
Rail (tons)	28,200	78,300	101,800	181,000	715,000
Water consumption (gpd)	112,500	312,000	406,000	720,000	2,853,000

* Per year.

The second test is based on varying the industry mix to correspond with characteristic functional relationships between types of industry and city size, as examined in Chapter IV. This test estimates costs of infrastructure for different industry mixes, respectively suited to small, medium, and large cities. Results of the second test and comparisons with the cost test for the proportionate mix are presented in Chapter VI.

Site Selection and Off-Site Facility Requirements in Five Test Cities

The need for common criteria and procedures in selecting potential sites for new industry and related residential areas in the test cities was noted in Chapter II. Common criteria are needed in order to draw valid inferences, however qualified, on the effects on incremental costs of the size of city area and required connections with existing city facilities.

Assumptions and Criteria for Site Selection

The basic assumptions for site selection are described below. However, these are not underlying concepts or theories of economy, but broad guidelines which result in the selection of comparable sites and provide a basis for estimation of infrastructure requirements.

1. Locate industry and housing areas adjacent to each other. It might be argued that costs for facility development under this assumption would be higher than if employees were assumed to find housing in scattered locations about the city, where existing facilities could be utilized. On a first-cost, current basis, this might be true; however, the eventual addition to the cities' housing inventory of new dwelling units to replace the hitherto scattered vacancies must take place in any event if the city is to grow and maintain some semblance of balance between housing demand and supply. Accordingly, it was felt more realistic to provide totally new areas with neighborhood facilities and services adjacent to the industrial area itself.

2. Establish certain criteria from the standpoint of both (a) physical site development, and (b) industrial benefit. A rationale consistent in all cities could thus be made about the site selection. However, because of the difficulty of assessing economic benefits that might accrue over time to various industries, the trade-offs or interfaces between physical site development and industrial benefit are based, for the most part, on field observation and judgment only, optimized site selections being neither implied nor intended.

Criteria relating to physical development of the site were:

1. The site should be on lands not physically developed at the time of the field investigation--i.e., vacant lands void of on-site facilities.

2. The site should be of sufficient size to accommodate the total industrial mix within one continuous boundary.

3. The site should be near to other vacant land of sufficient size to meet worker housing requirements within a reasonably close distance.

4. The site should not be located on lands topographically unsuitable, such as in low-lying lands subject to inundation, or where river banks are subject to overflow, or where soil conditions are poor, or in rock excavation or outcrop areas.

5. The site should be located on lands where environmental factors such as noise, odor, smoke, and vibration emanating from the new industries would be the least disturbing to neighboring areas.

6. The site should be located on lands where the prevailing winds are favorable to neighboring uses and the town center.

7. Existing zoning and proposed land use plans of the city should guide but not necessarily restrict selection.

8. The site should be located within or close to the present corporate boundary.

9. The site should not be located where land prices are unreasonable compared to those of other existing industrial sites in the particular city. Although land costs shall be taken into account in choosing among candidate sites, they should be separately classified so that intercity land price differences will not enter into infrastructure cost comparisons.

The foregoing were considered as independent criteria for selection purposes, each being evaluated on its own merits, with as many criteria as possible being satisfied in the final selection. On the other hand, criteria about proximity to, or capacity of, highways, railways, and water or power supply lines are economically interdependent with the selection process. Independent, quantitative guidelines in this regard were therefore not predetermined prior to commencing the field work.

Criteria relating to industrial benefits were that, insofar as possible, the chosen site should:

1. Have convenient access to a major intercity highway; where one leg of the highway goes through the city center, the site should

be on that side of the city closer to the stronger intercity industrial linkages. The connection to this highway should not pass through residential or other use areas where the flow of normal truck traffic would be impeded, or where safety to pedestrians or residents would pose a problem.

2. Not be located on or have principal access to, a highway subject to undue delays caused by railroad grade crossings, unusually narrow bridges, or other causes.

3. Have reasonable access to the central business district (CBD) of the city.

4. Be located near a railroad spur or mainline track suitable for spur track switching.

5. Be located convenient to packaged freight shipping and receiving facilities.

6. Where practicable, contain the residential neighborhood on the same side of the highway, railway, river, or canal as the industrial site.

With the use of gross acreage requirements (described below) as well as the foregoing criteria, three to six sites for the new industrial development were examined in each of the five cities under consideration. A fixed number of candidate sites for all cities were not examined because of the differing site opportunities of each city. Those sites within, or adjacent to, the cities' corporate limits that essentially satisfied the selection criteria were visited and considered for selection. As a matter of interest to the reader, six sites were examined in city A, five in city C, four in cities B and D, and three sites in city E. The indication here is that sites for consideration became harder to find as the cities increased in size, at least based on the acreage requirements and selection criteria used.

Physical Characteristics of Development

In all cases, the physical characteristics assumed are that the industrial mix area should:

1. Occupy one site, although of varying configuration. (The cost model described below assumes for facility cost development purposes a single site of rectangular shape--in actuality, however, shapes would be quite diverse among the cities.)

2. Be situated on flat lands requiring only finish grading.

3. Contain only single story factory buildings.

4. Have the same floor-to-plot* and plot-to-site ratios.

5. Have the same percentage of gross area devoted to allied uses such as common parking, storage, staging, administrative, canteen, park, recreation, and other related uses.

6. Have no perimeter walls (although allowance for screen planting is considered).

7. Have electric power and telephone facilities.

8. Have a street lighting system with fixtures mounted on utility poles.

9. Have a piped water system, including delivery to individual factory and housing plots.

10. Have a piped sanitary sewage and industrial waste collection system with disposal into either an existing municipal interceptor line or into a new disposal works.

11. Have a storm drainage system consisting of open drains, culverts, and channels extending to a natural waterway.

12. Have a road network serving the entire area; however, have a railroad spur track system directly serving only 20 percent of the industrial plots (the remaining portion would utilize common on-site freight loading facilities).

It is assumed that each industry within the development will receive its entire water supply from the common system; therefore, no in-plant wells are considered. To ensure the minimum of deleterious effects on surrounding lands, in-plant treatment of industrial process wastes are assumed (see subsequent section on Facility Standards and Cost Estimation). It is recognized that for many years, these latter assumptions may be difficult to realize; however, they are made for the sake of greater cost comparability between the test cities.

Further, in view of the need for comparability, 90 percent of the work force and their families are assumed to occupy a single housing development similar in facility development to that just described for the industrial mix area (except of course for the industrial waste and railroad spur systems). Ten percent of the work force would live in neighboring villages or other small clusters outside the municipal service area.

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* Plot area is that lot area composed of structure, plinth, and open space, leased or sold to industry.

The Selected Sites and Off-Site Requirements

The selected sites in the median, largest, and smallest test cities are discussed below in regard to their location and their off-site demands upon existing systems. Off-site requirements in the other two cities are more or less analogous to those in the median test city, with exceptions as noted. Demands affecting on-site facilities for both the industrial area and its concomitant residential neighborhood area are discussed in the subsequent section, on Facility Standards and Cost Estimation.

The Median Test City (C)

General. Figure 18 shows the selected industrial and residential sites for City C along with other features pertinent to this analysis. The chosen locations are on either side of a major intercity highway just beyond the municipal limits and are approximately 1-1/2 miles from the city CBD. The rail line abutting the northerly property line of the industrial site is of narrow gauge and serves no useful purpose to the site's intended use; however, a paralleling broad gauge spur track can easily be constructed alongside in order to provide a rail connection to the railway and freight handling yards shown on the figure. The 116 acre industrial parcel is flat; it is expected that only moderate grading would be required to fill a few swampy pockets existing in its easterly portion. The 205 acre area on the south side of the highway considered for residential use is somewhat more undulating. It also contains a few swampy portions, as well as abandoned kiln pits. Design of the neighborhood would ultimately have to take these features into account.

The price of these properties in 1967 rupees approximates Rs. 3.00 to Rs. 3.50 per square yard, which was found to be comparable to other lands of potentially the same uses, having abutting highway access, and in excess of a mile from the CBD.

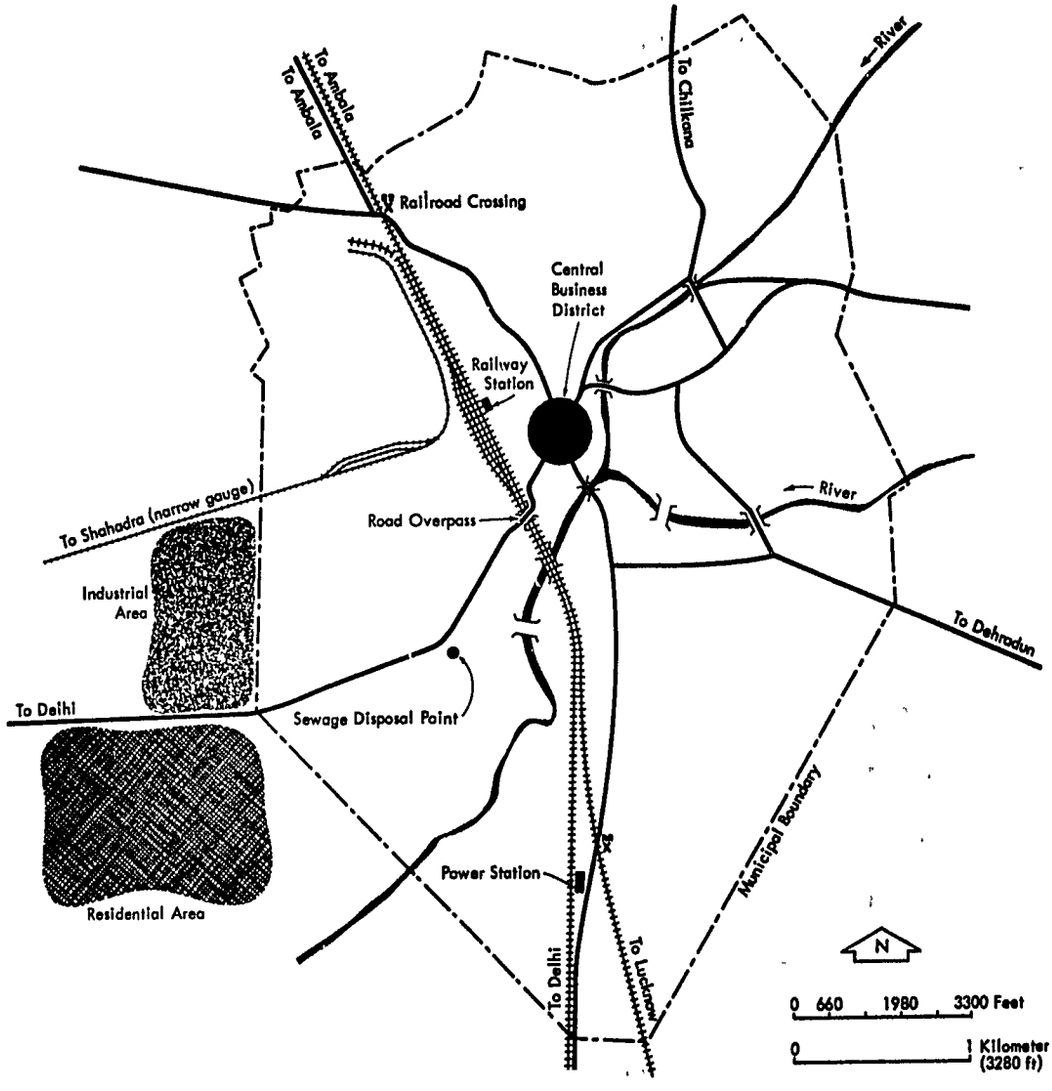
Transport. Three off-site traffic elements are considered--pedestrian (including bicycle), railroad car, and highway vehicle (fuel or animal driven).

In city C, of the 6,830 employees, all except 230 are assumed to work a daytime shift (typically 8 a.m. to 5 p.m.). Ten percent of these daytime workers have been assumed to live in villages out of town and should not need to cross the highway, at least at the location of the industrial site. There remain some 6,000 workers who daily must cross the highway going to and from work.

Assuming three controlled crossing points along the frontage of the residential area (approximately 1/3 mile apart), 2,000 pedestrians and bycycles would cross at each point during a one-hour period, or an average of 33 per minute. This would essentially stop through traffic on

Figure 18

CITY C



the highway for one hour in the morning, one hour in the evening, and no doubt, close to one hour at noontime. Even disregarding such absolute estimates, to suggest three crossings in less than one mile of highway for the order of magnitudes indicated presents an extremely unsafe situation for the pedestrian and untenable delays for faster moving traffic such as scheduled trucking and public transit. Accordingly, one pedestrian overpass and two electrically operated control signals are considered necessary between the two sites and are included in the cost estimates. The overpass, 80 feet in length,* includes ramp approaches for bicycle use.

Table 87 shows the total annual tonnage of the new industry mix in City C to be 101,800 tons by rail and 95,100 tons by road. Considering the types and magnitudes of raw materials received and products shipped by each of the industries included in the mix, the table classifies total tonnage by terminating and originating. The difference in weight between these two classes is due to in-plant consumption, waste, and reuse. In the case of rail, both the terminating and originating tonnage is by rail into and out of the city, but not necessarily to and from the industrial site itself. It is expected that some 75 percent of the indicated rail tonnage will be direct off-loaded and loaded at the site. The remainder would be conveyed by road vehicle (truck or cart) between the site and the city's freight depot.

Table 87

INCREMENTAL TONNAGE, CITY C
(Metric Tons)

Mode	Total	Terminating	Originating	Ratio
Rail*	101,800	71,200†	30,600‡	7:3
Road	95,100	42,300	52,800	4:5
Total	196,900	113,500	83,400	4:3

* Intercity tonnage: i.e., loading points at both site and freight depot.
† Terminating 71,200 tons would divide 53,400 tons direct to site and 17,800 tons off-loaded at city's freight depot.
‡ Originating 30,600 tons would divide 23,000 tons direct from site and 7,600 tons on-loaded at depot.

* Eighty feet of clear span allows for future widening of the highway without interference from the pedestrian bridge abutments.

The road tonnage is thus 60,100 tons (42,300 plus 17,800) terminating and 60,400 tons (52,800 plus 7,600) originating at the site. Assume for the moment that one third of this might be conveyed by bullock cart or other company conveyance; the potential of some 80,000 tons or an average of 270 tons per working day, would justify a drayage office to be located on-site. (At an 8-ton haulage loading, 33 fully loaded truck movements could be expected daily.) Assuming the establishment of such an on-site truck loading and unloading facility we can now examine the off-site road traffic movements in Table 88.

Industrial site ingress and egress by roadway present no unusual problems from a traffic volume standpoint; peak hour movements are not high, at least for vehicles moving at speeds from 15 to 25 miles per hour. However, the problem here (assuming the indicated bullock cart movements are not far overstated) is that the slow moving conveyances will cause slow-ups at the points of connection to the highway and at congestion points between the site and the CBD, as well as, of course, aggravate the current problem on Indian highways today--the conflict between animal drawn and fuel powered vehicles. Widening of the intercity highway and its bridge over the railroad tracks just southwest of the CBD will no doubt be required some time in the next ten years; however, it is difficult to assess direct responsibility for their costs. The effect and location of general population growth, of other highway oriented industry developing along the common highway, of trends toward greater use of fuel powered vehicles (two and three wheel, private automobile, and transport truck), and of new bypass roads or loop highways cannot be reasonably judged. Accordingly, specific requirements for improving the existing off-site road system are not included in the derivation of incremental costs.

Off-site roadway requirements that are included consist of (1) two highway intersections, one each at the easterly and westerly limits of the site (approximately 0.4 miles apart); (2) sufficient pavement to accommodate free right turning lanes into and out of the site; and (3) 2,000 lineal feet of storage lane (500 feet either side of each intersection) located between the existing highway and the fronting lands.

For rail traffic, the 53,400 tons annually arriving by spur track at the industrial site itself suggests an average terminating tonnage of 178 tons, or approximately 9 freight cars daily.* Considering a peak factor of 3, as many as 27 cars may enter and leave the site in any one day. (Note that because of the 7 to 3 ratio previously discussed, some 12 of these cars would leave the site empty.) Considering 10 hours of switching activity per day, a 4,000 foot off-site spur track connection between the site and the main line could handle this traffic, and is included in the cost estimate. The on-site loading and unloading facilities, as well as the main yard switching capabilities, would be the critical elements. On-site requirements of spur trackage, dock side trackage,

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* Assumes a capacity of 20 tons per car.

Table 88

HIGHWAY TONNAGE AND TRAFFIC, CITY C

Tonnage and Traffic	Terminating at Site			Originating at Site		
	Commercial Truck	Company Truck	Bullock Cart	Commercial Truck	Company Truck	Bullock Cart
Tonnage						
From highway* (tons)	38,100	2,100	2,100	47,600	2,600	2,600
From railroad depot† (tons)	6,000	5,900	5,900	2,600	2,500	2,500
Total (tons)	44,100	8,000	8,000	50,200	5,100	5,100
Average tons/day‡	147	27	27	167	17	17
Number of vehicles						
Average day§	18	5	27	21	3	17
Peak day (3x)	54	15	81	63	9	51
Peak hour**	5.4	1.5	8.1	6.3	0.9	5.1
Total one-way truck movement/peak hour	7			7		
Total one-way bullock cart movement/peak hour			8			5

* 90 percent by commercial truck, 5 percent by industry owned truck, 5 percent by bullock cart.
† 33 percent by commercial truck, 33 percent by industry owned truck, 33 percent by bullock cart.
‡ Assumes 300 working days per year.
§ Assumes 8 tons per commercial truck; 5 tons per industry truck; 1 ton per bullock cart.
** Ten percent of peak day.

and goods handling and storage facilities are reported in the section entitled Facility Standards and Cost Estimation. The lack of information about separation of railway facility from handling expenditures precludes derivation of off-site costs to be incurred at the city's switching yard.

Sanitary Sewage. A 48-in. sanitary sewer is currently being constructed approximately 0.7 miles east of the study site. This line, serving a major portion of the city, will connect to a new screening, settling, and pumping plant, where the effluent will be passed on to a river which flows to the southwest. In the design of this sewer line and plant, the city's master plan for sanitary sewers considers the flow of sewage from the area occupied by the industrial mix and its residential neighborhood. Some 3,600 lineal feet of 24-in. concrete pipe will be required for connection to this city system. This pipe size will allow for the inclusion of the pretreated industrial liquid waste expected to be generated from the industries located within the mix area.

Water Supply. Because of the inability of existing water systems in this city to provide water in the quantities anticipated, and the distances from existing pumping and storage areas, no off-site facilities or connections are planned. Connections between the industrial and neighborhood areas would be made to provide for greater efficiency in design and service; however, because the sites are adjacent to each other, connectors are considered as part of the on-site systems.

Power. A city power substation is located 1-1/4 miles from the site. Allowing for angle points and property lines, it is estimated that 8,000 lineal feet of overhead 11 kv line with a capacity of 7,000 kva will be required for this off-site connection. Existing 11 kv lines can be found closer to the site; however, the Power Department advises that either the total capacity of these lines is now being utilized, or existing excess capacity is already allocated to meet other near term demands.

When full site development occurs in ten years, the incremental costs that may be incurred by increases in the city's substation, or for that matter in the grid system itself, are extremely complex. The city substation was reported to have substantial 132 kv/33 kv transformer capacity. As load develops, 33 kv/11 kv units are successively installed. For purposes of cost derivation, it is assumed that the incremental industry and residential load (5,470 kva) is assigned the cost of a new 33 kv/11 kv transformer unit of 7,500 kva capacity, to be located at the city substation.*

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* Where incremental facilities that are required for new industry are themselves relatively indivisible, power substations being a case in point, for this study their full costs are attributed to the incremental industry, even though other city users would ultimately benefit from the joint economies in their establishment.

Drainage. As the land generally slopes to the west away from the city, off-site open drainage ditches are contemplated. From the industrial site to the river, 4,500 lineal feet of brick lined open channel would be required.

Telephone. The requirement of new telephone connections in each test city starts with one connection for each prospective new factory, an equivalent number of residential connections, and connections for public agencies and commercial uses. The total new requirement works out at about 5.3 connections per 1,000 added population, corresponding to the present mean for the 18 cities. On the whole, therefore, no increase in per capita availability of telephone service is provided. In the case of city C, phone connections currently number 4.1 per 1,000 population, so that a slight increase over the present standard is provided for the industrial increment. An overhead cable of at least 160 pairs would be required from the site to the city exchange, with a corresponding increase in exchange capacity. Lack of capital cost information precludes costing of these requirements in our estimates.

Schools. Primary and higher secondary schools are planned on-site in the residential neighborhood. Also, as schools of higher education or trade schools are not considered in this study, there are no physical off-site cost requirements. Administrative costs per student at the district level were not obtainable and therefore are not included in the cost analyses.

The One Million City (E)

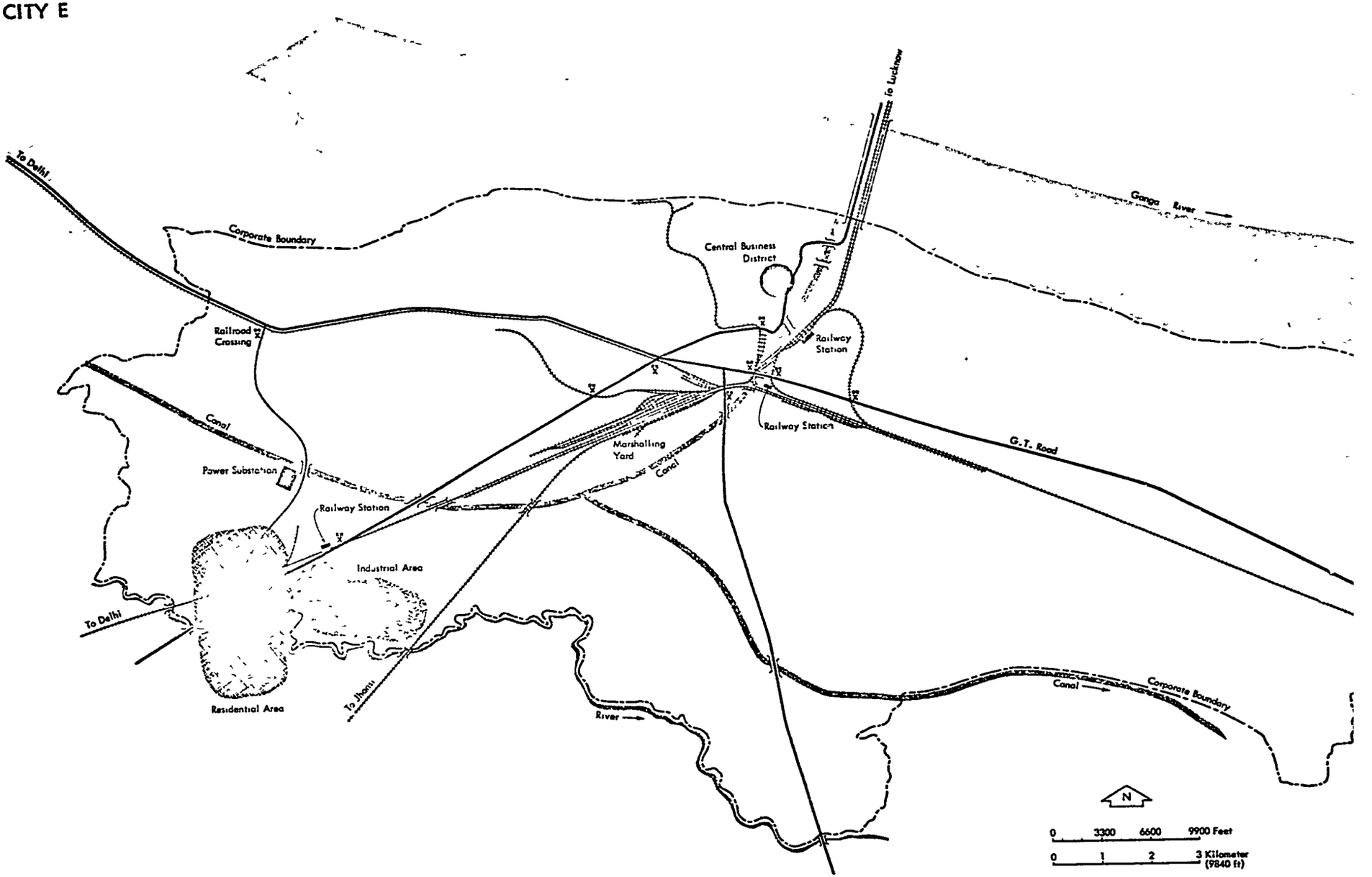
General. Figure 19 shows the selected industrial and residential sites for the largest test city, E, in relation to the principal existing city systems. The selected industrial site is located between a major highway and small river at the southwesterly limits of the city. Land development for industrial purposes is currently under way by the State Industrial Corporation immediately to the northeast of the site.

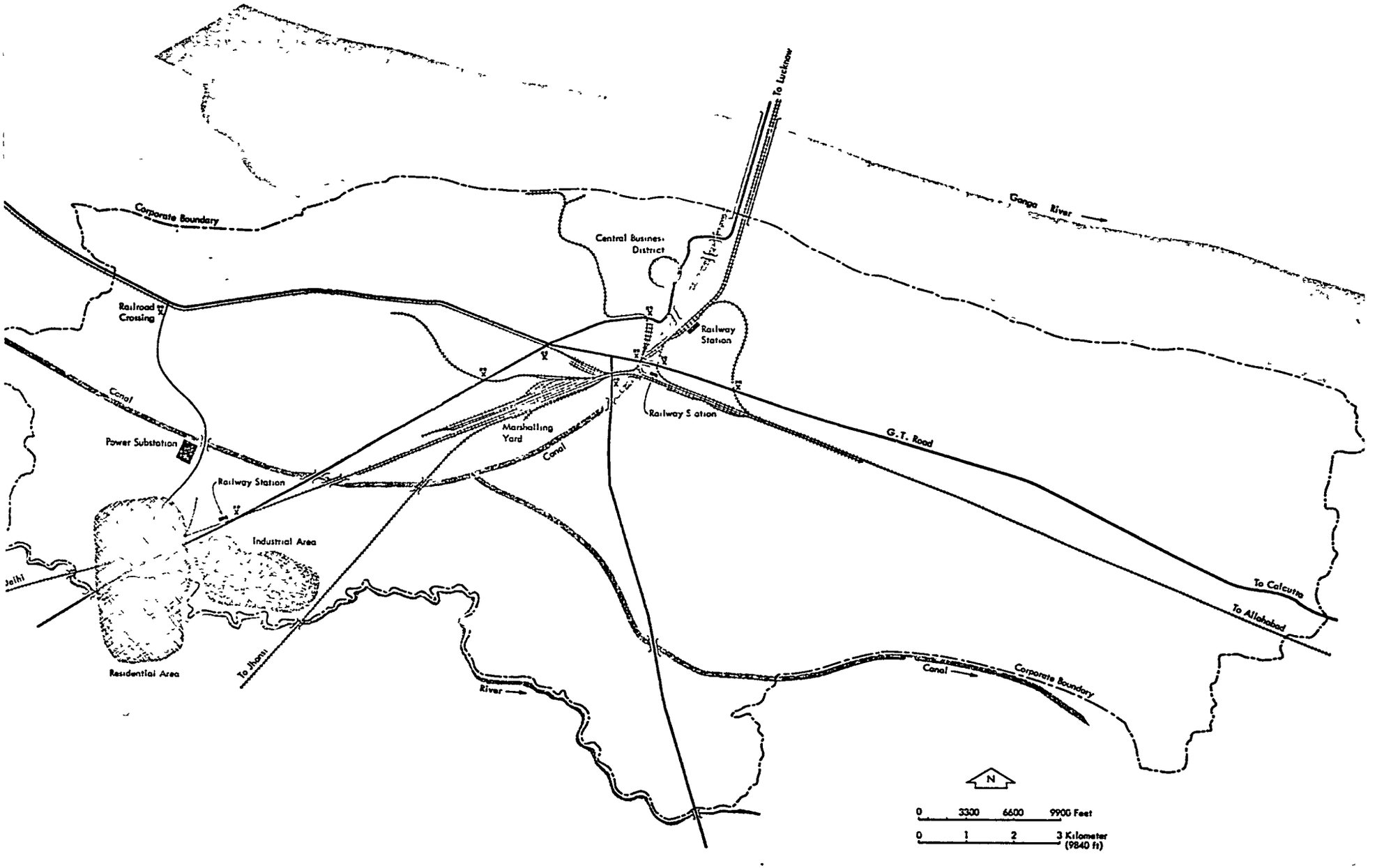
The large land requirement for the residential area (over 1,400 acres), dictated that it be situated on both sides of the highway. Although this major road, as well as the broad gauge rail line to Delhi, would divide this community, it can be reasonably imagined that such a super-neighborhood (200,000 population) would not develop totally on only one side of these arteries. Because of the very significant movement of employees between the industrial site and the residential community, 50 percent of the land requirement of the latter is taken as being on the south side of the highway abutting the mix area.

It is realized the river might normally be a constraint against neighborhood expansion on its southerly side. However, such lands are also included in the study area, the reason again being the magnitude of the

Figure 19

CITY E




To Lucknow
Corporate Boundary
Ganga River
Central Business District
Railroad Crossing
Railway Station
Canal
Railway Station
Marshalling Yard
Canal
G.T. Road
Power Substation
Railway Station
Industrial Area
Delhi
To Calcutta
To Allahabad
Residential Area
To Jhansi
River
Canal
Corporate Boundary
N
0 3300 6600 9900 Feet
0 1 2 3 Kilometer (9840 ft)

development and the need to bring more employees close to their place of work. Also, the river could serve as a logical design feature in providing for open space between different subneighborhoods.

The sites are near a small local railroad station, 4 miles from the railroad marshalling yards, and some 7 miles from the CBD. The industrial site has close access to two rail lines; however, the Grand Trunk (G.T.) Road (Delhi-Calcutta) is 5 miles away by highway or some 3-1/2 miles by a narrow existing city street.

Land prices varied between Rs. 6.50 per square yard for the residential area north of the highway to Rs. 9 per square yard for the industrial site.

Table 89

INCREMENTAL TONNAGE, CITY E
(Metric Tons)

Mode	Total	Terminating	Originating	Ratio
Rail*	715,000	500,000†	215,000‡	7:3
Road	668,000	297,000	371,000	4:5
Total	1,383,000	797,000	586,000	4:3

* Intercity tonnage; i.e., loading points at both site and freight depot.

† Terminating 500,000 tons would divide 375,000 tons direct to site and 125,000 tons off-loaded at city's freight depot.

‡ Originating 215,000 tons would divide 161,000 tons direct from the site and 54,000 tons on-loaded at depot.

Transport. Under the same assumptions as described for city C, pedestrian, railway, and highway traffic will be discussed. It is considered that (1) a substantial number of slow moving vehicles would use the highway, (2) the road tonnage would most probably move continuously throughout the day without a well-defined peak, and (3) incoming and outgoing movements would occur more or less equally. With these considerations, the approximate peak 2,000 vehicle movements per day (see Table 90)

Table 90

HIGHWAY TONNAGE AND TRAFFIC, CITY E

Tonnage and Traffic	Terminating at Site			Originating at Site		
	Commercial Truck	Company Truck	Bullock Cart	Commercial Truck	Company Truck	Bullock Cart
Tonnage						
From highway* (tons)	267,400	14,800	14,800	334,000	18,500	18,500
From railroad depot† (tons)	41,600	41,700	41,700	18,000	18,000	18,000
Total	309,000	56,500	56,500	352,000	36,500	36,500
Average tons/day‡	1,030	188	188	1,173	121	121
Number of vehicles						
Average day§	128	38	188	146	24	121
Peak day (3x)	384	114	564	438	72	363
Peak hour**	38.4	11.4	56.4	43.8	7.1	36.3
Total one-way truck movement/peak hour	50			51		
Total one-way bullock cart movement/peak hour			56			36

* 90 percent by commercial truck, 5 percent by industry owned truck, 5 percent by bullock cart
† 33 percent by commercial truck, 33 percent by industry owned truck, 33 percent by bullock cart
‡ Assumes 300 working days per year.
§ Assumes 8 tons per commercial truck; 5 tons per industry truck; 1 ton per bullock cart.
** Ten percent of peak day.

conflicting with the existing grade level railroad crossing near the local highway station present an untenable point of traffic congestion.*

Accordingly, the study's industrial mix would require the construction of a grade separated crossing of the railroad and highway. The northerly leg of this bridge crossing would connect by a frontage road to the highway at a point beyond the railroad station, as well as connect to a widened city street providing direct access to the G.T. Road for arriving or originating traffic to the northwest. A bridge with two vehicle lanes plus sidewalks on each side is considered for costing purposes; the total cost of this overcrossing is attributed to the study's industrial site and its housing area. Slow moving traffic and use of this bridge by proposed industry to the north and east of the study site would create the need for at least one more lane. However, the costs for a structure larger than the minimum discussed are not felt assignable to the study's industrial mix.

In regard to the movement of bullock carts, which roughly equal the number of trucks on the road system, at least three points of access would be necessary over and above those on the fronting street connecting to the southerly leg of the new overcrossing. One point of access can be directly onto the existing highway and two points onto the future street network of the industrial lands to the north and east.

The crossing of the highway with the railroad tracks just south of the G.T. Road would also exhibit increased vehicle delays, adding to the congestion which now occurs at this point. As in the case of city C, widening of the highway from the site to the G.T. Road, or modifications to the rail crossing (near G.T. Road) are subject to many external forces. As rational prorating of their costs is not feasible, they are mentioned but not included in cost comparisions.

In addition to the pedestrian lanes provided on the new overcrossing structure adjacent to the side, two additional pedestrian bridge crossings are envisioned. Also, two 2-lane river crossings would be required as part of the on-site neighborhood community development.

As far as railroad freight traffic is concerned, the 375,000 tons annually terminating at the site is the controlling movement. For the approximate 300 operational days per year, the average daily tonnage would be some 1,250 tons, or approximately 62 rail cars.† Using a peak factor of three, it is conceivable that some 186 cars may enter the site during a peak day. At this rate, the industrial site's rail freight traffic would effectively pre-empt mainline traffic; therefore spur tracks are required direct from the marshalling yard system in lieu of direct

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* It is expected that the added vehicle movement southwesterly along the highway would be small, and that practically the total tonnage moved would be to or from the G.T. Road, the CBD, and the city's transport depots.

† At 20 tons per wagon.

connections to either the abutting main rail lines. A minimum of three spur tracks to the site are required.

For this largest of the industrial mix areas considered in the five city study, extensive new construction of the city's rail trackage, loading dockage, handling equipment, transit sheds, and administrative facilities will no doubt be required. Exhaustive study of railway facilities, operations, and accounting procedures would be required for meaningful derivation or allocation of incurred incremental costs. Accordingly, as with all other test cities, such potential off-site costs are mentioned but not included in city-cost comparisons.

Sewage and Industrial Waste. The river paralleling the southerly corporate boundary line offers the closest outlet for sanitary and pretreated industrial wastes. The city's present sanitary sewer collection system is approximately two-thirds complete; however, its distance from the new sites indicates the inappropriateness of considering flowage into this system, given the river outlet. The magnitude of the flows, especially when the industrial and residential requirements are combined, offers scale economies and lower per capita costs for a central disposal facility discharging into the river southeast of the industrial site. Further, the greatest dilution of industrial liquid wastes would occur in the collection tanks prior to discharge into the river. The screening, settling, and pump system would have a capacity of 48 mgd and discharge a daily average of 13 acre feet into the river.

Water Supply. Referring to the discussion of on-site water supply and distribution in the Facility Standards and Cost Estimation section, below, no off-site water development costs are required.

Power. The new thermal power house and 132 kv substation are favorably located some 6,300 feet from the industrial site and 1,000 feet from the northern limit of the residential area. The electrical engineering consultants' report contemplates a 132 kv line from the substation to the industrial site, where a new 132/11 kv substation of 40,000 kva capacity would be installed to serve requirements of both sites. The residential demand would be met by an 11 kv feeder from this receiving station.

Drainage. Because of the closeness of the river, no off-site drainage facilities are contemplated. As discussed earlier, this river can serve as an ideal design feature as it traverses the residential community.

Telephone. Provision of 5.3 new telephone connections per 1,000 added population, as described above, does not meet the present standard of 8.7 per 1,000 experienced in the one million city. This is the second highest per capita number in the 18 cities studied, exceeded only by

Jullundur's 14.9. For comparab[illegible] 5.3 per 1,000 figure built up from requirements of incremental industry and related users is nevertheless applied in city E as well as the other test cities. In order to maintain the city's present standard, an additional expenditure would be required but it is difficult to associate this cost with the industrial increment.

City A - The Smallest of the Test Cities

General. Selected industrial and residential sites in the smallest test city are shown in Figure 20. The industrial site is located between the G.T. Road and railroad to Delhi, close to the southwesterly limits of the city. Land development for industry purposes has taken place northeast of the site. The selected site for the residential area is across the G.T. Road, a little southeast of the industry site.

Transport. Under the procedure of analysis chosen for testing the research hypothesis, the assumptions made about rail and road tonnage movements are essentially the same as described for the median city C and the largest city E, as shown in Table 91.

Table 91

INCREMENTAL TONNAGE, CITY A
(Metric Tons)

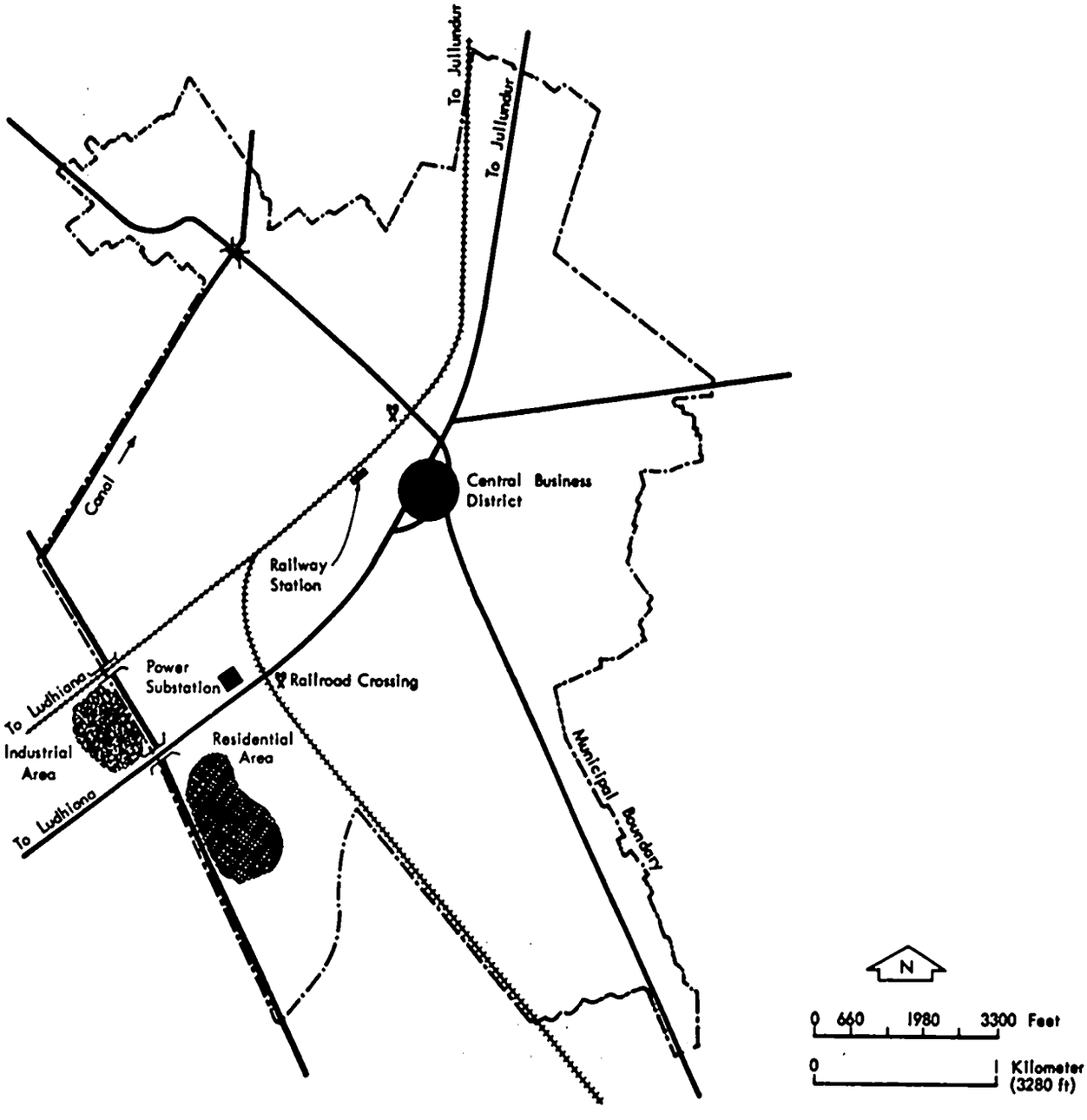
Mode	Total	Terminating	Originating	Ratio
Rail*	28,200	19,700†	8,500‡	7:3
Road	26,300	11,700	14,600	4:5
Total	54,500	31,400	23,100	4:3

* Intercity tonnage; i.e., loading points at both site and freight depot.
† Terminating 19,700 tons would divide 14,800 tons direct to site and 4,900 tons off-loaded at city's freight depot.
‡ Originating 8,500 tons would divide 6,400 tons direct from site and 2,100 tons on-loaded at depot.

The total annual road tonnage is 16,600 (11,700 plus 4,900) terminating and 16,700 (14,600 plus 2,100) originating at the site. If one-third

Figure 20

CITY A



of this tonnage were to be transported over the road and highway network by bullock cart or company owned vehicle, 22,200 tons (or an average of 73 tons per day) could be considered as a potential market for private drayage firms. Because of this relatively small tonnage, truck loading facilities are not expected to develop on the 33-acre industrial site, but rather to be located in the area of the CBD. The proportionately greater use of bullock cart and company owned vehicles therefore entering and leaving the site (as compared to those in larger cities) is illustrated in Table 92.

The daily entries into and out of the site are minimal, and little if any traffic congestion should occur. The slow moving vehicles leaving the site merging with faster highway traffic would suggest a storage lane between the paved highway section and the industrial area. As this would be more for reasons of safety than traffic capacity, 250 feet of ingress and egress lane on both sides of the site's single connection should be adequate.

Because of the lack of information about the average daily traffic on the G.T. Road, as well as the volume of train movement and delay times experienced or to be experienced at the rail crossing about a half mile east of the site, it is difficult to assess what impact the industrial mix may have upon either this road or the rail crossing. In any event, the highway traffic generated by the industrial mix is considered the least disruptive to the existing road system of all city sizes studied, not by reason of city size, but rather by the size of the mix. Stated another way, the traffic generated is small and the receiving facility (1-1/2 to 2 lanes of pavement with a single rail track crossing) is a typical minimum of many cities, small or even very large.

The rail tonnage of 14,800 tons terminating annually at the site is similarly very nominal. In fact, it could be argued that the average of 49 tons (say 2.5 rail cars) entering daily would hardly warrant on-site rail service. However, because of the existence of a main rail line immediately adjacent to the site, the first costs of a track switch and some 100 feet of connecting spur to an on-site loading station would be far exceeded by the recurring annual costs of hauling an equivalent tonnage by bullock cart, hand cart, or company truck.

Further, an on-site spur and loading facility offers road network advantages of reducing congestion, delay, maintenance, and traffic control as well as offering an attraction to certain segments of industry.

Some 1,650* one-direction employee crossings of the highway are expected to occur between the industrial area and its neighborhood residential area. A cycle track on each side of the highway, with a controlled crossing between the industrial and housing areas, would be appropriate both from the standpoint of employee requirements and highway traffic.

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* 1,890 total employees, less 10 percent living out of the city and 3 percent working nonday shifts.

Table 92

HIGHWAY TONNAGE AND TRAFFIC, CITY A

Tonnage and Traffic	Terminating at Site			Originating at Site		
	Commercial Truck	Company Truck	Bullock Cart	Commercial Truck	Company Truck	Bullock Cart
From highway and truck terminal* (tons)	5,900	2,900	2,900	7,400	3,600	3,600
From railroad depot† (tons)	1,600	1,600	1,700	700	700	700
Total (tons)	7,500	4,500	4,600	8,100	4,300	4,300
Average tons per day‡	25	15	15	27	14	14
Average daily vehicles§	3	3	15	3	3	14
Peak day (3x)	9	9	45	9	9	42

* 50 percent by commercial truck, 25 percent by industry owned truck, and 25 percent by bullock cart.
† 33 percent by commercial truck, 33 percent by industry owned truck, and 33 percent by bullock cart.
‡ Assumes 300 working days per year.
§ Assumes 8 tons per commercial truck, 5 tons for industry owned truck, 1 ton per bullock cart.

Electric Power. The existing 33 kv/11 kv substation now services distribution transformer substations having a combined capacity of 11,625 kva. For the incremental mix, additional 33 kv/11 kv transformer capacity of 2,000 kva would be required, serving an 11 kv line 1800 feet to the industrial site.

Specific Off-Site Requirements in Other Test Cities

City B. As indicated in Figure 21, a city power substation (capacity 17 mva) is located 0.40 miles from the industry site. It is estimated that 2,100 feet of overhead 11 kv line with a capacity of 7,000 kva will be required for off-site connection. The housing area site is adjacent to this city station and the off-site cost is negligible. For purposes of cost derivation it is assumed that the incremental industrial and residential load (4,205 kva) is assigned the cost of a new 33 kv/11 kv transformer of 7,500 kva capacity at the city substation.

The creek paralleling the westerly municipal boundary offers the closest outlet for sanitary and pretreated industrial wastes from the industrial area. An estimated 1,300 feet of 12-in. concrete pipe would be required for connection from the area to the disposal works to be provided on this creek. The existing canal south of the municipal boundary is considered for disposal of sanitary wastes from the residential area. An estimated 500 feet of 15-in. concrete pipe would be required for connection to the disposal works to be provided on this canal.

City D. The city 132 kv/33 kv transformer station is close by. It is estimated that 1,600 lineal feet of overhead 33 kv line will be required for off-site connections, serving a transformer substation at the industrial site having 20,000 kva capacity.

As for rail requirements, the connecting spur track to the city power station runs through the selected industry site, as shown on Figure 22. It is estimated that this would be utilized by the industry mix for spur track switching on-site. However, the estimated peak requirements of 48 wagons per day for the industry area need augmentation to the main spur from the Delhi railroad. For easy stacking of rail cars before switching to the industry spur, a loopline of 1,500 lineal feet is provided parallel to the main line and is considered in off-site costs.

The main highway link from the industry site to the G.T. Road crosses the said Delhi railroad at its present alignment and a level crossing is considered as an off-site requirement. However because costs on level crossing equipment are lacking, they are not included in the formal cost data.*

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* However, they are included in Table 94, which presents items not costed.

Figure 21

CITY B

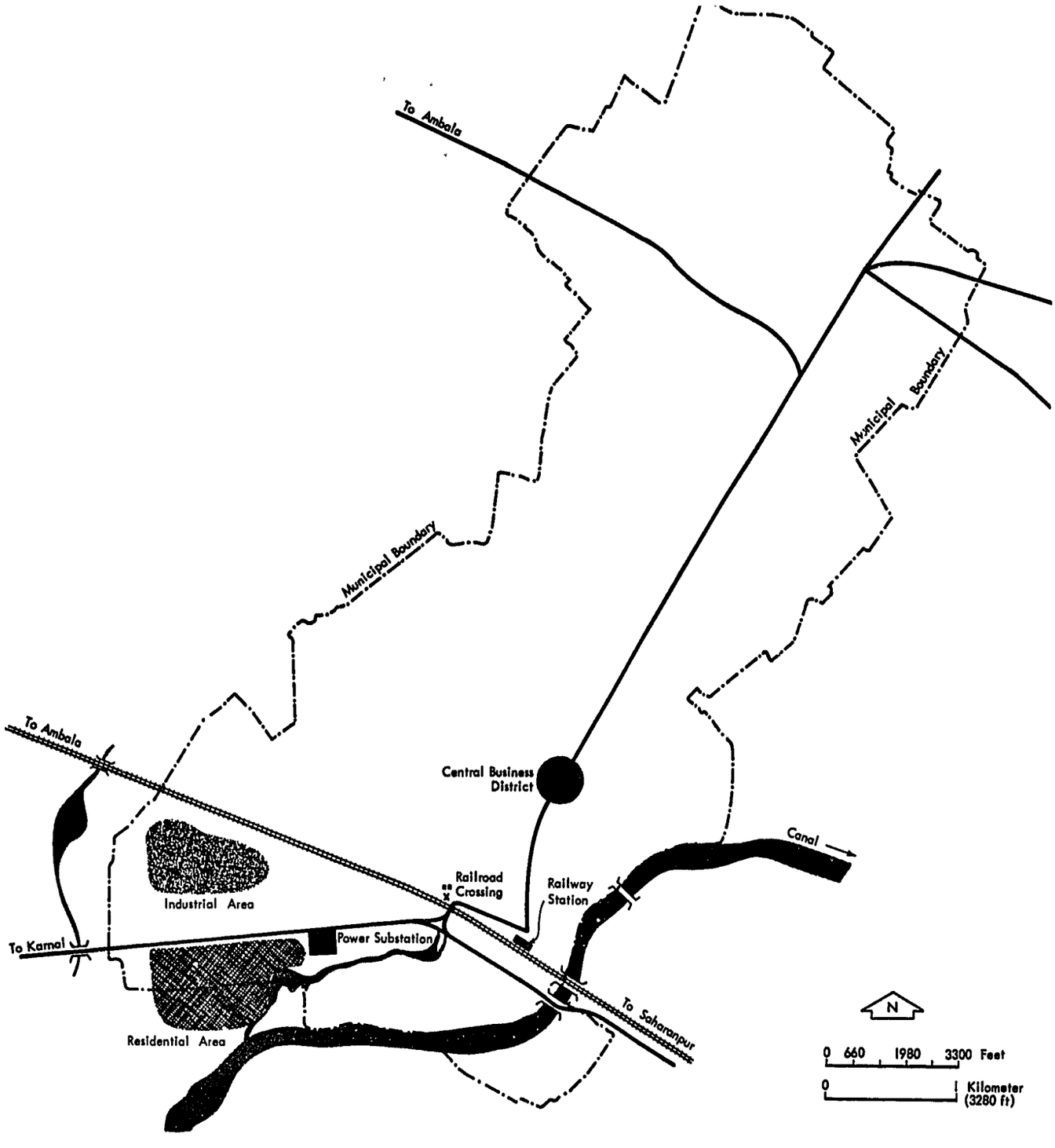
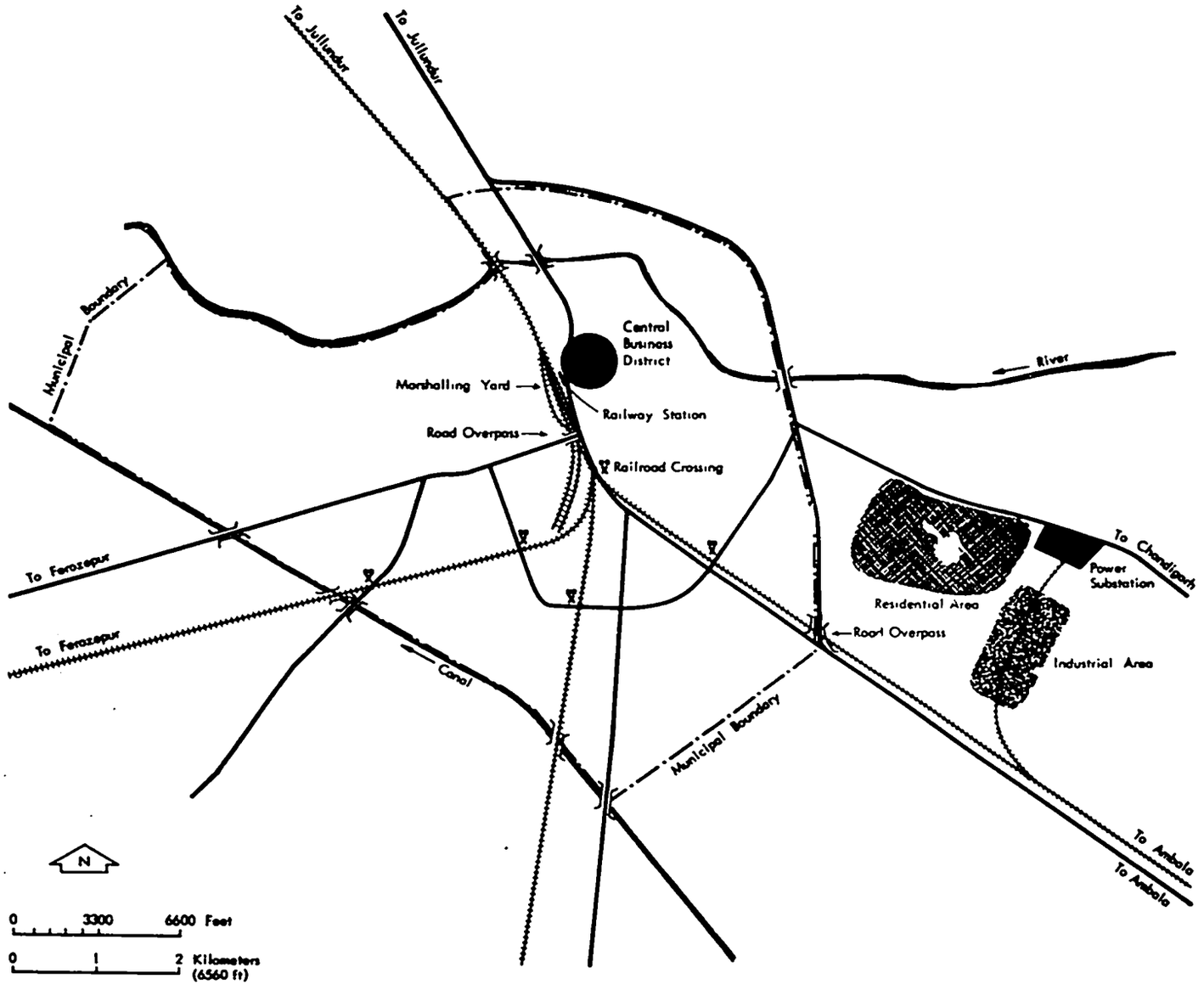


Figure 22

CITY D



The existing creek northwest of the selected sites is considered for disposal of sanitary and pretreated industrial liquid waste and storm water flows. An estimated 6,150 feet of 33-in. concrete pipe would be required for connection from the industrial area to the sewage disposal works to be provided on this creek.

Summary of Off-Site Requirements

The above requirements for connecting the new industrial and residential areas to existing city systems and for off-site facilities not now available, such as sewage disposal works, are tabulated in summary form on Table 93. It will be observed that these are mostly off-site lineal connectors. Power transformer receiving substations are the principal nodal element. Since they serve a connective function to existing systems, and their proposed physical location is based simply on the relative technical and economic advantages of siting at the existing stations or at the new site, power substations are classified as off-site elements. Public services--fire and police protection and refuse disposal--for which cost distinction between off-site and on-site is difficult, are included in the off-site table.

Off-site transport requirements identified above for which costs are not fully or strictly allocable to the industrial increment are summarized in Table 94.

Facility Standards and Cost Estimation

This and the following section provide an analysis of the cost consequences of various infrastructure elements and compare the costs of infrastructure for incremental industry in the five test cities. Allowance is made for the costs of all types of facility development required in a city, such as provision of utilities (water, sewerage, electricity, and telephone); public services (fire protection, refuse disposal, police protection); educational and public health facilities; and transportation networks (roads and rail). The methods of estimating costs and the way the various costs enter into the total "infrastructure costs" are explained.

It is necessary, in order to compare the relative costs in the five cities, to consider the types of increments which are provided. The focus is on incremental industry and its urban facility requirements. Two types of areas are considered--the industrial and the residential areas. In all the test cities, the residential area is more of a neighborhood development, as opposed to a new entity or city by itself. The residential area includes social, educational, and commercial facilities for the population employed in the proposed industrial area. All development of physical facilities is by no means complete and new. Some elements are additions to those existing in the city or necessitate expansion of city facilities--for instance, fire protection, police protection, road and bridge widening, and public utility expansions. The choice of a site for

Table 93

OFF-SITE INFRASTRUCTURE REQUIREMENTS - FIVE TEST CITIES

	City Size				
	A	B	C	D	E
Industrial area					
Power					
New transmission line (lineal ft)					
11 kv double circuit OH line	1,800	2,100	8,000		
33 kv double circuit OH line				1,600	
132 kv single circuit OH line					6,300
33/11 kv transformer station (mva)	2	7.5	7.5	20	
132/11 kv transformer station (mva)					40
Rail					
New spur track with switch (lineal ft of broad gauge line 90/BSS over timber sleepers)	100	100	4,000		10,200
Additional loop track (lineal ft of broad gauge line, 90/BSS)				1,500	
Sewerage					
New sanitary trunk sewer					
12-in. R.C. hume pipe (lineal ft)	†	1,300	†		
18-in. R.C. hume pipe (lineal ft)				2,800	
New sewage disposal works					
Pumping plant, screening chamber, and collection tanks (mgd capacity)	†	1.05	†	†	†
Roads and highways					
Widening of existing highways (lineal ft of 10 ft metalled width)	500	500	2,000	1,000	6,500
New road connections (lineal ft of 20 ft metalled width)		1,100		5,250	11,900

Table 93 (continued)

	City Size				
	A	B	C	D	E
Industrial area (cont.)					
New cycle tracks (lineal ft of 9 ft metalled width)	2,200				
New pedestrian bridges (lineal ft of 8 ft width; steel and timber)			80		
New traffic signals; electrically operated and controlled (sets)	1	1	1	1	2
New railroad crossings (level crossing-broad gauge track)				1*	
Residential area					
Power					
New transmission line (lineal ft of 11 kv single circuit OH line)	1,000				
Sewerage					
New sanitary trunk sewer					
10-in. R.C. pipe (lineal ft)	1,400				
15-in. R.C. hume pipe (lineal ft)		500	†	†	
New sewage disposal works					
Pumping plant, screening chamber, and collection tanks (mgd capacity)	†	1.71	†	†	†
Drainage					
Outfall drains from the proposed areas; trapezoidal section (ft)	1,400*			3,000*	
Roads and highways					
New road connections (lineal ft of 20 ft metalled width)	400				†
New pedestrian bridges (lineal ft of 8 ft width; steel and timber)		100			240

Table 93 (continued)

	City Size				
	A	B	C	D	E
Residential area (cont.)					
New traffic signals; electrically operated and controlled (sets)			1		1
New road culverts (no.)					2*
Serving both areas					
Sewerage					
New sanitary trunk sewer					
12-in. R.C. hume pipe (lineal ft)	2,640				
24-in. R.C. hume pipe (lineal ft)			3,600		
33-in. R.C. hume pipe (lineal ft)				6,150	
New sewage disposal works					
Pumping plant, screening chamber, and collection tanks (mgd capacity)	1.02		3.60	7.65	30.33
Drainage					
Outfall drains; trapezoidal section (ft)	2,650*		4,500*	6,150*‡	
Roads and highways					
Widening of existing city streets (lineal ft of 11 ft metalled width)					14,700
New road connections (lineal ft of 20 ft metalled width)					6,800
New road overpass (lineal ft of 32 ft wide road section reinforced concrete construction, with sidewalks)					1,700*
Telephones					
No. of new connections and additional exchange capacity (@ 5.3 per 1,000 population)	45	125	163	289	1,143

Table 93 (concluded)

	City Size				
	A	B	C	D	E
Serving both areas (cont.)					
Fire protection					
Additional number of fire-fighting units	§	§	§	1	4
Additional number of firemen (6 per fire-fighting unit)	§	§	§	6	24
Police Protection					
Additional number of policemen (@ 1.4 per 1,000 population)	12	33	43	76	302
Refuse disposal					
Additional number of employees (@ 2.5 per 1,000 population)	21	59	77	136	539

Note: Requirements for fire and police protection and refuse disposal are based on norms developed by analysis of India field data in Chapter III. See corresponding sections in Chapter III for details.

* Considered in requirements but not costed.

† Combined service for both industrial and residential areas.

‡ Pipe culvert--90 in. diameter.

§ Additional complete units are not required; however, augmentation to the central fleet is considered in cost estimates.

Table 94

OFF-SITE INFRASTRUCTURE REQUIREMENTS NOT STRICTLY ALLOCABLE TO INCREMENTAL INDUSTRY - FIVE TEST CITIES

Description for Both Industry and Housing Areas	City Size				
	A	B	C	D	E
Roads and highways					
Improvements at bottleneck points	--	Level crossing along highway, improvement to rotary junction	Highway overpass over RR, 400 ft x 12 ft, plus approaches	Level crossing along G.T. Road	Level crossing near CBD
Widening of bridges/culverts	Culvert, 18 ft x 10 ft	--	Culvert, over canal, 12 ft x 12 ft	--	Bridge over canal
Local public transport system to and from main CBD	--	Distance to CBD 3 miles	Distance to CBD 2 miles	Distance to CBD 5 miles	Distance to CBD 8 miles
Railroad system					
Additional city yard trackage (ft @ 30 ft per car)	90	300	390	690	2,700
Additional city goods sheds (sq ft @ 100 sq ft per car)	300	1,000	1,300	2,300	9,000
Additional railroad crossing	--	--	--	One level crossing along proposed road	--

each facility element is based on the most suitable connection with existing city facilities, taking into account the amount and kind of existing resources (underused or otherwise) in alternative locations. Development cost estimates are presented separately for on-site facilities in the industrial area and the residential area, for off-site facilities, and for combined facilities serving both areas.

In order to make the costs comparable, it is essential to work with similarly constituted standards throughout. Given the number of persons to be served, and therefore the size of facility, the most influential factor affecting costs is the standard of development proposed. The required provision of physical facilities for the specified population has been based on various types of evidence. Inevitably the evidence is based on documented planning standards currently in use for recently planned areas or city extensions rather than on less documented unplanned existing urban areas. The design standards adopted in calculating the facility requirements for the two areas are shown in Appendix C (Tables C-2 to C-6). Based on these and on the incremental industry proposed, the requirements of various physical facilities and land use are derived.

The Industrial Area

The land allocated for the industrial area comprises land required for the industrial plots as well as for roads, rail, open spaces, facilities and services. Based on plot and facility requirements and the design standards specified in Appendix C, Table C-2, the land requirements shown in Table 95 result for the median test city C.

There are a number of ways in which the comparative cost estimates can be attempted. In this study, full development of the site with all physical facilities is assumed completed by the year considered in estimating the industrial increment--1977. However, costs are given for 1967 prices. Unit costs for facilities reported in Chapter III are applied after adjustment to Bareilly, 1967.

For cost comparison, a basic unit cost per area (rupees per acre) is used for the standards and inputs of facility development envisaged. Detailed cost estimates for most facilities have been made for the median test city module (city C), and these have been applied in estimates for other cities. The site module envisaged for the industrial area is rectangular, 600 yards x 936 yards. Although in actuality, configurations are quite diverse among the cities, use of a rectangular module helps to evaluate on-site requirements such as size of plots and blocks and lineal measurements for utilities and transport networks.

The physical facilities required are dependent on the number and type of industries included in the mix. Industry requirements, which were quantified in Table 86, determine the scale of facilities, their spatial distribution on-site, and their interrelation to existing systems in the city. Detailed on-site facility and land requirements in the five test cities are shown in Table 96 for industrial areas, for residential areas, and for facilities serving both areas.

Table 95

LAND REQUIREMENTS FOR INDUSTRY AREA
CITY C

Use	Acres	Percentage
Industrial plots	80.0	69.0%
Roads	17.4	15.0
Parks and open spaces	11.6	10.0
Other (includes rail sidings, public uses)	7.0	6.0
	116.0	100.0%

Industrial Plots - Size and Number

Size of Plot (sq yd)	Number of Plots	Frontage (yd)	Total Area (sq yd)
1,000	6	150	6,000
2,100	8	280	16,800
3,600	6	270	21,600
5,000	5	250	25,000
6,600	7	420	46,200
9,000	5	375	45,000
12,000	1	80	12,000
15,000	4	400	60,000
15,625	3	375	46,875
18,000	6	600	108,000
Total	51	3,200	387,475 or 80 acres

Table 96

ON-SITE INFRASTRUCTURE REQUIREMENTS - FIVE TEST CITIES

Requirements	City A	City B	City C	City D	City E
Population size (000)	48	132	212	323	1,070
Industrial area					
Gross area (acres)	33	91	116	210	828
Power:					
Load capacity (kva)*	1,300	3,622	4,711	8,367	33,111
Rail:					
On-site tonnage terminating by rail (000 tons)	15	41	53	95	375
No. of cars per day (300 days per year)	2.5	7.0	9.0	16.0	62.0
No. of cars at on-site goods siding (21% of peak terminating; peak = 3 x average daily)	2.0	5.0	6.0	10.0	40.0
Length of on-site goods siding (feet @ 30 ft per car)	60	150	180	300	1,200
Sewerage					
Sewage flow (mgd)	0.13	0.35	0.46	0.81	3.21
(cfs @ 90% of water supplied)	(0.24)	(0.65)	(0.85)	(1.50)	(5.96)
Design peak (mgd)	0.39	1.05	1.38	2.43	9.63
(cfs @ 3 x DWF)	(0.70)	(2.00)	(2.60)	(4.50)	(17.90)
Size of outfall sewer (diameter in in.)†	8	12	15‡	18‡	36‡
Drainage					
Storm water outflow§ (cfs)	36	100	127	231	911
Residential area					
No. of industrial workers to be housed (90% of total industrial workers)	1,700	4,725	6,147	10,890	43,110
Housing area population (000) (5 persons per dwelling)	8.5	23.6	30.7	54.5	215.6
Gross area (acres) (gross density @ 30 dwelling units per acre; 1 dwelling unit per worker)	57	158	205	363	1,437
Dwelling units					
No. of dwellings to be costed (20% of the total)	340	945	1,229	2,178	8,622
Power					
Load capacity (kva)* (@ 100 watts per industrial worker)	210	583	759	1,344	5,322

Table 96 (concluded)

Requirements	City A	City B	City C	City D	City E
Residential area (continued)					
Sewerage					
Sewage flow (mgd)	0.21	0.57	0.74	1.74	6.90
@ 80% water supplied (cfs)	(0.39)	(1.06)	(1.37)	(3.23)	(12.80)
Design peak (mgd)	0.63	1.71	2.22	5.22	20.70
3 times DWF (cfs)	(1.17)	(3.18)	(4.11)	(9.69)	(38.40)
Size of outfall sewer (diameter in in.)†	10	15	16‡	27‡	52‡
Drainage					
Storm water outflow§ (cfs)	63	174	226	399	789**
Schools					
Schoolgoing children					
Primary (@ 112 per 1,000 population)	950	2,650	3,440	6,100	24,140
Higher secondary (@ 87 per 1,000 population)	740	2,060	2,670	4,740	18,750
Hospitals					
Number of hospital beds (@ 2 to 2.5 per 1,000 population)	25	50	60	130	430
Serving both areas					
Water					
Industrial					
Water for industry use (000 gal)	113	312	406	720	2,853
Additional (000 gal)	28	79	103	182	719
Total industrial use (mgd)	.14	.39	.51	.90	3.57
Residential					
Water required @ 30 gpcd (mgd)	.26	.71	.92	2.18††	8.62††
Total gallons per hour, peak (000)	39	108	140	294	1,165
Total OHT capacity (000 gal)	78	216	281	588	2,330

Note: Requirements based on norms developed by analysis of India field data in Chapter III. See corresponding sections in Chapter III for details.

* Power factor assumed at 0.9.
† Manning's formula: n = 0.013.
‡ Outfall sewer later to be combined for flow from both areas; section size shown is for this area flow only.
§ Calculated by Rational Method (Intensity 2.75, Run-off factor 0.40).
** For one-half of housing area.
†† Calculated @ 40 gpcd.

Costs for the industry area cover site development, public utilities, and transport networks. Cost of land acquisition and factory buildings are excluded for reasons explained earlier. Costs are derived mostly from unit costs discussed in Chapter III, although additional unit costs are utilized for some requirements for which comparative cost analysis was not undertaken. These include rail spurs, traffic signals, and pedestrian overpasses, for which cost data are given in Appendix C, Table C-7.

As discussed in earlier sections on site selection and existing facility capacity, it was determined in each test city that new water systems would be required for the envisaged industrial expansion. Available existing capacities are neither adequate nor suitably located to serve the additional requirements. For each test city, a water supply system including wells, pumping stations, overhead storage tanks, and distribution lines is therefore provided on-site. To gain economies of scale and integrated design, the system is planned to serve both industrial and residential areas.

The Residential Area

In addition to site development, utilities, and transport, significant costs for the residential area are for housing, schools, and hospitals. The assumptions made with regard to requirements for these social infrastructure elements are central to the cost implications of the study.

Housing is costed for 20 percent of the industrial employees assumed to reside in the city. This cost assumption is based on the estimate that approximately this proportion of housing costs of urban industrial workers in the study region is currently met by public funds, through either loan, subsidy, or direct grant.

Housing plinth area requirements for different income levels are given in Table C-3 of Appendix C. Five family members per dwelling are assumed. The gross density assumed in all five cities is 30 dwellings per acre. The number of stories and the net density, however, change for the largest city E. The reason for the departure is explained by a comparison of requirements from the median test city C to the largest city E, as seen in Table 96. The numbers of schools and hospital beds required, as well as amenities such as shops, parks, and open spaces, increase in direct proportion to the population concentration (from 31,000 to 216,000). For the larger population, additional community facilities are required, including commercial services, community centers, religious buildings, and recreational buildings and areas. Correspondingly, the spatial requirements of community amenities and facilities become more pronounced in the population concentration 216,000, introducing a need for conservation and maximum utilization of space in city E in order to achieve comparable standards in all cities. Classical dissertations on best utilization of space in metropolitan cities (population 1 million and over) for two and three dimension changes are many in the literature; this question is not the main focus of this research.

Accordingly, in city E a net residential density of 500 persons per acre is sought to be achieved through four story buildings. For comparative purposes, the breakdown of land requirements for 10,000 population for the two net densities is given in Table 97.

Water system requirements for cities D and E present another departure, in per capita terms, which requires explanation. With increase in population being housed, the need of water for civic uses and for the types of community facilities mentioned above increases, necessitating a larger supply. This when expressed per capita gives an increased figure for the larger concentrations of population. Accordingly, in the standard for water supply, in cities D and E, per capita figures of 40 gallons per day are assumed as compared to 30 gpd per capita in cities A, B, and C. At the outset, this may appear to be an increase in standards, but in reality is required to maintain equivalent standards for the larger population concentrations in which added functions must be performed.

Hospital requirements are derived from standards mentioned in Table 50 in Chapter III. These standards, which optimize on the building efficiency per bed (for larger hospitals as measured by number of beds), appear as scale economies in cost estimates although there is no reduction in standard of service.

Analysis of Infrastructure Costs

Table 98 presents total and annual capital costs, annual maintenance and operation (AMO) costs, and total annual costs of infrastructure in the five test cities, by facility. Service lives for each facility and element, taken as the basis for calculation of annual capital costs, are listed in Appendix C, Table C-8, with the related capital recovery factors for 5 percent and 10 percent interest rates. Facilities are subdivided in Table 98 by industrial area, residential area, and "Serving Both Areas." On-site and off-site cost distinctions are introduced as a starting point for evaluating the share in the total cost package of those elements which serve to link the new developments with existing city facilities or to augment those facilities. As explained earlier, off-site costs cover the elements shown in Table 93.

It should be pointed out, as indicated in Table 93, that the total cost figures do not include capital costs of telephone lines, storm water drains, refuse disposal, and road overpasses on major highways, because of lack of such capital costs in the field data. The estimated capital costs are therefore somewhat lower than would be the case if all items were costed. Noncosted elements are mostly common to all cities, with the exceptions shown in Table 93. Their magnitude as compared to total costs is not considered sufficient to preclude valid cost comparisons among the five cities.

Table 97

LAND UTILIZATION FOR 10,000 POPULATION
CITIES C AND E

	City C		City E	
Characteristics				
Gross density (persons per acre)	150		150	
Net residential density (persons per acre)	377		500	
Number of stories	2		4	
Use	Acres	Percent	Acres	Percent
Residential	26.5	40%	20.0	30%
Roads	10.0	15	12.0	18
Parks and open spaces	12.8	19	13.0	19
Shops	1.2	2	1.2	2
Schools	10.8	16	11.1	17
Hospitals	3.9	6	3.9	6
Other public use	1.5	2	5.4	8
Total	66.7	100%	66.6	100%

Table 98

COSTS OF INFRASTRUCTURE BY AREA AND FACILITY IN FIVE DEVELOPMENTAL CITIES
(Rs. 000, Bareilly 1967)

Area and Facility	City A				City B				City C				City D				City E			
	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost
ON-SITE																				
Industrial area																				
Site development, excl. roads	348	35	1	36	960	97	4	100	1,223	123	5	128	2,215	223	9	232	8,732	880	34	914
Roads	130	16	3	19	359	44	8	51	458	56	10	66	828	101	18	119	3,266	398	70	469
Rail	83	9	†	9	309	32	†	32	355	37	†	37	499	53	†	53	1,970	208	†	208
Power	580	62	24	86	1,598	170	47	217	2,037	217	56	273	3,685	393	93	486	14,511	1,549	346	1,896
Sewerage	93	9	negl.	10	255	26	1	27	325	33	2	34	589	59	3	62	2,322	233	12	244
Subtotal	1,233	131	29	159	3,481	368	59	426	4,398	466	72	538	7,818	829	122	951	30,830	3,268	463	3,730
Residential area																				
Site development, excl. roads	286	29	1	30	791	80	4	84	1,027	104	5	109	1,818	184	10	193	7,198	727	38	765
Roads	335	41	5	46	928	113	13	127	1,201	147	17	164	2,133	260	31	291	8,412	1,029	122	1,152
Power	416	43	17	61	1,154	120	34	154	1,497	156	41	197	2,650	276	67	343	10,492	1,094	250	1,344
Sewerage	180	18	1	19	498	50	2	52	646	65	3	68	1,143	115	6	120	4,527	451	23	477
Houses	1,744	176	26	202	4,849	189	73	562	6,306	636	95	731	11,171	1,127	168	1,295	51,325	5,177	770	5,946
Schools	768	82	115	197	2,139	229	322	552	2,774	298	420	717	4,923	528	742	1,270	19,479	2,089	2,935	5,024
Hospitals	735	75	83	158	1,184	121	166	286	1,454	148	199	347	2,899	295	431	726	7,142	730	1,425	2,155
Subtotal	4,462	464	249	712	11,543	1,202	614	1,817	14,908	1,553	780	2,333	26,741	2,785	1,453	4,238	108,604	11,299	5,563	16,862
Serving both areas																				
Water	424	43	66	109	1,105	113	150	264	1,346	138	166	304	2,579	264	213	177	9,741	1,001	759	1,760
Total on-site	6,119	638	343	981	16,129	1,684	824	2,508	20,653	2,156	1,018	3,174	37,138	3,877	1,789	5,666	149,221	15,568	6,785	22,353
OFF-SITE																				
Industrial area																				
Roads	71	8	negl.	8	77	9	1	10	129	15	1	16	155	18	5	24	376	45	14	59
Rail	7	1	†	1	7	1	†	1	280	31	†	31	105	12	†	12	714	79	†	79
Sewerage					129	13	1	14					56	6	negl.	6				
Subtotal	78	9	negl.	9	213	23	2	25	409	46	1	47	316	35	5	41	1,090	123	14	137
Residential area																				
Roads	7	1	negl.	1	73	9		9	53	6		6					228	27		27
Sewerage	18	2	negl.	2	169	17	1	18												
Subtotal	25	3	negl.	3	242	26	1	27	53	6		6					228	27		27
Serving both areas																				
Roads																	265	32	13	46
Power	172	18	7	25	507	53	15	68	554	58	15	73	918	96	23	119	2,101	252	57	309
Sewerage	146	15	1	16					389	40	2	42	797	82	4	86	1,550	161	8	168
Telephones	‡	‡	10	10	‡	‡	28	28	‡	‡	37	37	‡	‡	65	65	‡	‡	257	257
Fire	3	negl.	2	3	8	1	7	8	10	2	8	10	11	2	14	16	45	7	56	63
Police	13	1	4	6	36	4	12	16	46	5	16	20	82	8	28	36	326	33	111	111
Refuse	‡	‡	23	23	‡	‡	72	72	‡	‡	83	83	‡	‡	147	147	‡	‡	582	582
Subtotal	333	35	48	82	551	58	134	192	1,000	104	160	265	1,808	188	281	470	4,587	484	1,085	1,569
Total off-site	437	46	48	95	1,006	107	137	244	1,462	156	161	318	2,125	224	287	511	5,905	635	1,098	1,734
Total	6,556	684	391	1,075	17,135	1,791	961	2,752	22,115	2,312	1,180	3,492	39,263	4,101	2,076	6,177	155,129	16,203	7,883	24,086

Note: Detail may not add to totals due to rounding.
negl. = negligible, less than Rs. 500.

* Annual capital cost @ 10 percent interest.
† AMO assumed by railway.
‡ Capital cost not included.

Similarly, the off-site transport requirements which were shown in Table 94 are not costed or included in cost estimates. They are presented to illustrate the agglomeration effects of incremental industry which are not easily quantifiable or allocable solely to the increment itself.

Perspective on Facility Costs

In analyzing total infrastructure costs, it is useful first to examine their breakdown by major type of facility. This can be done from the consolidated facilitywise summary of costs presented in Table 99, in rupees and percentages. The behavior of unit costs for each facility in relation to city size can be gauged from the breakdown of costs per gross acre, presented in Table 100.

The largest share of costs in all cities is for housing, even though it is costed only for the 20 percent of urban industrial employees estimated to be housed with assistance from public funds. Housing accounts for nearly 19 percent of total annual infrastructure costs in the smallest city A. Costs of housing when evaluated per gross acre as in Table 100 are stable for cities A, B, C, and D, but the change from two to four story dwellings in city E causes an increase of unit housing costs by 16 percent. Accordingly, housing rises to nearly 25 percent of total annual costs in the largest city E.

Schools account for the next largest share of total annual costs. More or less constant in unit costs, schools take from about 18 to 20 percent of the annual infrastructure cost bill in each test city.

Power distribution, hospitals, and water supply are the next largest facilities in terms of total annual costs. Each exhibits substantial economies of scale, most clearly seen in Table 100. In the case of power and water systems, scale economies are primarily realized in annual maintenance and operating costs, being more moderate in capital costs. Hospital capital costs fall substantially with city size except in city D, annual maintenance and operation costs for hospitals being more stable except for a significant fall from city A to city B.

Road costs, averaging 7 percent of total annual costs, tend to fall slightly per gross acre from cities A to D, rising slightly in city E. The increase in the largest city E would be somewhat greater if costs for the new road overpass serving both industrial and residential areas were included.

The implications for economic and social policy of the facility breakdown of infrastructure costs can best be seen when major utility and transport costs are allocated separately to industrial and residential areas. This analysis is undertaken in the concluding section of the chapter.

Table 99

ANNUAL COSTS BY FACILITY
Annual Capital, AMO, Total Annual, Percentage Distribution
(Rs. 000, Bareilly 1967)

	Annual Capital Costs* City					Annual Maintenance and Operation City					Total Annual Costs City					Total Annual Costs Percentage Distribution City				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Site development, excl. roads	64	177	227	407	1,607	2	8	10	19	72	66	184	237	425	1,679	6.1%	6.7%	6.8%	6.9%	7.0%
Roads	66	175	224	379	1,531	8	22	28	54	219	73	197	252	434	1,753	6.8	7.2	7.2	7.0	7.3
Rail	10	33	68	65	287	†	†	†	†	†	10	33	68	65	287	0.9	1.2	1.9	1.1	1.2
Power	123	343	431	765	2,895	48	96	112	183	653	172	439	543	948	3,549	16.0	16.0	15.6	15.3	14.7
Water	43	113	138	264	1,001	66	150	166	213	759	109	264	304	477	1,760	10.1	9.6	8.7	7.7	7.3
Sewerage	44	106	138	262	848	2	5	7	13	43	47	111	144	274	889	4.4	4.0	4.1	4.4	3.7
Houses	176	489	636	1,127	5,177	26	73	95	168	770	202	562	731	1,295	5,946	18.8	20.4	20.9	21.0	24.7
Schools	82	229	298	528	2,089	115	322	420	742	2,935	197	552	717	1,270	5,024	18.3	20.0	20.5	20.5	20.8
Hospitals	75	121	148	295	730	83	166	199	431	1,425	158	286	347	726	2,155	14.7	10.4	9.9	11.7	8.9
Telephones	‡	‡	‡	‡	‡	10	28	37	65	257	10	28	37	65	257	0.9	1.0	1.1	1.1	1.1
Fire	negl.	1	2	2	7	2	7	8	14	56	3	8	10	16	63	0.3	0.3	0.3	0.3	0.3
Police	1	4	5	8	33	4	12	16	28	111	6	16	20	36	144	0.6	0.6	0.6	0.6	0.6
Refuse	‡	‡	‡	‡	‡	23	72	83	147	582	23	72	83	147	582	2.1	2.6	2.4	2.4	2.4
Total	684	1,791	2,312	4,101	16,203	391	961	1,180	2,076	7,883	1,075	2,752	3,492	6,177	24,086	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Detail may not add due to rounding.
negl. = negligible.

* Annual capital cost @ 10 percent interest.
† AMO assumed by railway.
‡ Capital cost not included.

Table 100

ANNUAL COSTS PER GROSS ACRE BY FACILITY
Annual Capital, AMO, and Total Annual Costs
(Rupees)

	Annual Capital Costs* City					Annual Maintenance and Operation City					Total Annual Cost City				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Site development, excl. roads	711	711	707	710	709	22	32	31	33	32	733	739	738	742	741
Roads	733	703	698	661	676	89	88	87	94	97	811	791	785	757	774
Rail	111	133	212	113	127	†	†	†	†	†	111	133	211	113	127
Power	1,367	1,378	1,343	1,335	1 278	533	386	349	319	288	1,911	1,763	1,692	1,654	1,567
Water	478	454	430	461	442	733	602	517	372	335	1,211	1,060	947	832	777
Sewerage	489	426	430	457	374	22	20	22	23	19	522	446	449	478	392
Houses	1,956	1,964	1,981	1,967	2,286	289	293	296	293	340	2,244	2,257	2,277	2,260	2,625
Schools	911	920	928	921	922	1,278	1,293	1,308	1,295	1,296	2,189	2,217	2,234	2,216	2,218
Hospitals	833	486	461	515	322	922	667	620	752	629	1,756	1,149	1,081	1,267	951
Telephones	‡	‡	‡	‡	‡	111	112	115	113	113	111	112	115	113	113
Fire	negl.	4	6	3	3	22	28	25	24	25	33	32	31	28	28
Police	11	16	16	14	15	44	48	50	49	49	67	64	62	63	64
Refuse	‡	‡	‡	‡	‡	256	289	259	257	257	256	289	259	257	257
Total	7,600	7,193	7,202	7,157	7,154	4,344	3,859	3,676	3,623	3,480	11,944	11,052	10,879	10,780	10,634
Percent to total annual costs	63.6%	65.1%	66.2%	66.4%	67.3%	36.4%	34.9%	33.8%	33.6%	32.7%					

Note: Detail may not add to total due to rounding.
negl. = negligible, less than Rs. 5

* Annual capital costs at 10 percent interest
† AMO assumed by railway
‡ Capital cost not included.

Annual Maintenance and Operation Costs

A reference to Table 100 will indicate that annual maintenance and operation costs decline by city size relative to capital costs. The share of AMO costs in total annual costs falls gradually but quite regularly from 36.4 percent in city A to 32.7 percent in city E. This is mainly due to the greater economies of scale in AMO costs than in capital costs for water and power systems, as noted above.

Public services (fire and police protection and refuse disposal), which average somewhat over 3 percent of total annual costs in all test cities, account for a higher share of annual maintenance and operation costs, increasing from 7.4 percent in city A to 9.5 percent in city E. Estimated unit costs of public services, based on costs as analyzed in Chapter III, are virtually constant in all test cities.

Evaluation of Off-Site Costs

The share of off-site costs within each cost category--annual capital, annual maintenance and operation, and total annual--is summarized in Table 101. As a proportion of total annual costs, off-site costs are relatively stable at about 9 percent in cities A through C, declining to 8.3 percent in city D and 7.2 percent in city E. The off-site share in capital costs accounts for most of this decline. The cause of the decline is therefore to be found among utilities and transport networks, which constitute by far the largest part of off-site capital costs. In order to analyze these changes more closely, variations in the off-site shares of capital costs for transport facilities and utilities are set forth in Table 102.

Power accounts for the largest share of capital costs classified as off-site, for receiving substations and transmission lines to city substations. The off-site share of the capital costs of power declines from 15.5 percent in city B to 8.7 percent in city E mainly because of economies of scale in the larger receiving substations. To the extent that distances from the city substation to the new development areas are greater with city size, this increased distance is less than proportionate to the increased power load.

For sewerage facilities, the next largest off-site element, the decline in off-site costs as a share of capital costs from city D to city E is explained mainly by nearness to the river, a local factor.

The off-site share in capital costs of roads falls steadily and substantially from 13.6 percent in city A to 4.7 percent in city D, then increases to 6.8 percent in city E. A study of the off-site road requirements specified in Table 93 does not suggest any clear cause for the decline, except perhaps in the general sense that developed road systems in medium size cities may require a degree of augmentation that is less than proportionate to the load imposed by major industrial expansions.

Table 101

OFF-SITE COSTS AS A PERCENT OF ANNUAL CAPITAL COSTS, AMO COSTS, AND TOTAL ANNUAL COSTS

City Size	Annual Capital Cost	Annual Maintenance and Operation	Total Annual Cost
48,000	6.7%	12.3%	8.7%
132,000	6.0	14.3	8.9
212,000	6.7	13.7	9.1
323,000	5.5	13.8	8.3
1,070,000	3.9	13.9	7.2

Again, the rise in the off-site share of road costs in the largest city is less than would be the case if all required elements were costed, even apart from congestion costs.

The most striking feature of off-site capital costs, however, is their relatively modest share in the total infrastructure cost package. Even for those facilities that have the largest off-site capital elements, off-site costs are a relatively modest part of total capital costs. The four facilities shown in Table 102 are responsible for from 94 to 98 percent of all off-site capital costs in the five test cities, but their combined off-site capital costs as a share of their overall capital costs are no higher than 18.5 percent in city A and fall to 10.7 percent in city E. This explains the position in Table 101, where for total infrastructure, the off-site share of capital costs is no higher than 6.7 percent in city A and falls to 3.9 percent in city E.

It will be noted that the underground source of water in the study region, permitting the siting of tubewells and related systems in various decentralized sectors of the city, as opposed to the use of larger mains and pumping facilities that would be required in many citywide systems based on river or reservoir sources, is one factor in the relatively low share of off-site costs.

As a general conclusion, nevertheless, the small share of off-site costs is an indication that the size of city area has a relatively modest influence on the direct unit costs of incremental infrastructure, except possibly in the largest test city where increased unit road costs are perceptible. The cost variations observed in Tables 101 and 102 are more attributable to scale economies in new facility components in the larger cities, and to reduced unit AMO costs for certain large city systems, than to the effects of distance or city area. The chief qualification, of course, would be with regard to the effects of city area on congestion costs, which are beyond the scope of this study.

Table 102

VARIATION IN ON-SITE AND OFF-SITE COMPONENTS OF ANNUAL CAPITAL COSTS FOR TRANSPORT FACILITIES AND UTILITIES (Rs. 000)

Facility	City A	City B	City C	City D	City E
Roads					
On-site	57	157	203	361	1,427
Off-site	9	18	21	18	104
Total	66	175	224	379	1,531
Share of off-site %	13.6%	10.3%	9.4%	4.7%	6.8%
Rail					
On-site	9	32	37	53	208
Off-site	1	1	31	12	79
Total	10	33	68	65	287
Share of off-site %	10.0%	3.0%	45.6%	18.5%	27.5%
Power					
On-site	105	290	373	669	2,643
Off-site	18	53	58	96	252
Total	123	343	431	765	2,895
Share of off-site %	14.6%	15.5%	13.5%	12.5%	8.7%
Sewerage					
On-site	27	76	98	174	687
Off-site	17	30	40	88	161
Total	44	106	138	262	848
Share of off-site %	38.6%	28.3%	29.0%	33.5%	19.0%
Total					
On-site	198	555	711	1,257	4,965
Off-site	45	102	150	214	596
Total	243	657	861	1,471	5,561
Share of off-site %	18.5%	15.5%	17.4%	14.5%	10.7%

Areal, Nodal, and Lineal Costs

Further perspective on cost differences related to city size is gained by classifying costs in a manner that reflects the influence of space, scale, and distance. In order to show contrasts most clearly, such a cost breakdown is undertaken for the smallest and largest cities in Table 103. We classify as "Areal Costs" those elements which involve extensive use of space and do not show pronounced economies or diseconomies of scale: site development including street lighting, housing, schools, and police and fire protection. "Nodal Costs" refer to those elements or components which essentially occupy a point in space and show scale economies: hopsitals, power receiving and distribution stations, water system wells, pumping stations, and overhead storage tanks, and sewage disposal plants. "Lineal Costs," as the name suggests, cover distribution and collection facilities whether or not they display scale economies: roads, railway spurs, power mains and distribution lines, water pipelines, and sewer lines. Table 103 summarizes these three categories in terms of annual capital costs per gross acre, for combined industrial and residential acreages. Annual maintenance and operation costs are not included because of the arbitrary assumptions thatwould be required, particularly for the large water and power AMO components, to allocate them between nodal and lineal categories.

Table 103

AREAL, NODAL, AND LINEAL COSTS

Cost Category	Annual Capital Cost per Gross Acre (Rs.)		Share of Total Cost (percent)	
	City A	City E	City A	City E
Areal	3,589	3,935	47%	55%
Nodal	2,194	1,517	29	21
Lineal	1,817	1,702	24	24
Total	7,600	7,154	100%	100%

Nodal facilities or components, in which scale economies are important, account for by far the largest decline in costs per acre from city A to city E. However, the share of such elements in total costs, which falls from 29 percent to 21 percent, is not large enough to cause a corresponding decline in total costs. The increase in areal costs per acre, attributable directly to multistory housing in the largest city, is sufficient to offset over half the decline in scalar components. The share of areal costs accordingly rises from 47 to 55 percent. Lineal costs per acre decrease moderately from the smallest to the largest city but maintain a constant 24 percent of total costs.

These patterns of change and stability in the aggregate weight of costs associated with scale and distance are instructive in qualitatively evaluating the effects of such factors as size of industry mix, secondary or induced employment, variations in population density, and congestion costs. These factors are considered in the next chapter, after completing the quantitative analysis of costs as related to city size.

Conclusion on the Research Hypothesis

One of the desiderata of the research project as stated in the India Research Plan is to test the hypothesis that "costs of industrial infrastructure are significantly related to the size of urban centers." The detailed statement of the hypothesis in Chapter II implies a cost curve which declines with increasing city size up to a point and then rises again when city size reaches a certain level.* This cost function is often expressed as a U-shaped curve with different sloping grades. In order to test this hypothesis, basically two kinds of data were analyzed: (1) cost functions of individual facilities which were then directly applied to the levels of infrastructure requirements related to industry mixes for different city sizes, and (2) infrastructure requirements of prospective industries whose scales of production were determined on the criterion of viability.

The present test of the research hypothesis deals with a situation in which the proportion of industries in the mix is constant in five test cities of different size. Infrastructure requirements are therefore also in constant proportions. For the second test, presented in the next chapter, the relationships have been varied to show the effects of industry mix requirements typical or characteristic of small, medium, and large city sizes.

The previous sections in this chapter have summarized the estimates and breakdown of infrastructure costs, presented as (1) capital costs, and (2) annual maintenance and operation costs. These two costs have also been expressed as total annual costs which, as explained, are the annual capital charge (interest and depreciation based on life periods of different facilities) plus annual maintenance and operation costs. For the hypothesis test, we analyze capital and annual costs as related to the two

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* If industrial infrastructure increments are assumed to be in direct proportion to the city size, then the hypothesis implicitly suggests that unit costs are high for a small industrial infrastructure increment, decrease as infrastructure increments increase until the most efficient scale of requirement is achieved, and then rise again as the level of increment further increases. Theoretically, a cost curve should have this characteristic since there is always a level of infrastructure which is more efficient than any other and on either side of which costs are higher. This is, of course, on the assumption of other things being equal.

major industry parameters, annual value added and total employees. First we give a table showing the total capital and total annual cost per unit of Rs. 1,000 value added and per employee for different city sizes. Similar details are then separately shown for industrial and housing areas.

A word of caution may be added at the outset of the discussion on the cost data. The extent to which variations seen in the tables should be attributed to city size influences is a question for considered judgment. Two significant endogenous elements that have entered the cost estimations are (1) indivisibility of facilities at some scale of requirement, and (2) variation in the design and configuration of social infrastructure facilities in the effort to achieve comparable standards among cities. Both of these have resulted in noticeable cost differences. The particular sense in which each can be regarded as a function of city size must be interpreted in light of the individual facility characteristics, discussed above.

We now present Table 104, which gives the crucial data on the total capital and annual costs of infrastructure, having direct relevance for the research hypothesis.

Table 104

TOTAL CAPITAL AND TOTAL ANNUAL COSTS OF INFRASTRUCTURE FOR INCREMENTAL INDUSTRY PER RS. 1,000 VALUE ADDED AND PER EMPLOYEE
(Rupees)

City Size		Costs per Rs. 1,000 Value Added		Costs per Employee	
		Capital	Annual	Capital	Annual
A	48,000	882	145	3,469	569
B	132,000	829	133	3,264	524
C	212,000	823	130	3,238	511
D	323,000	824	130	3,245	511
E	1,070,000	822	128	3,239	503

It is evident from the table that the unit capital or annual costs of infrastructure do not substantiate the hypothesis in its present form. Unit capital costs per Rs. 1,000 value added decline significantly with increase in city size to 132,000 population, slightly to the next size city, and then stabilize, instead of showing a rise as stipulated in the research hypothesis. This stabilization is true at least up to 1,070,000 population, the limit of city size tested in the study. It is significant that scale economies in unit capital costs become weak at city size

132,000, after which neither economies nor diseconomies are discernible. Since employment changes proportionately with value added in this first test, per employee capital costs follow the same pattern.

Unit capital costs for providing industry infrastructure, according to the table, are lowest for city size 1,070,000 and highest for the size group represented by 48,000 population. Expressed per Rs. 1,000 value added, capital cost in the smallest city is 7.4 percent higher than in the largest city. In the 132,000 city, capital cost per unit of value added is 0.9 percent above that of the largest city and 6 percent below that of the smallest city.

Compared to unit capital costs which begin to level off at the 132,000 city level, annual costs show a continuing small decline with increasing city size. This is explained by economies in annual maintenance and operation costs achieved with increase in scales of facility, rather than by capital cost differences. Table 104 shows a range from Rs. 128 to Rs. 145 in annual costs per Rs. 1,000 value added between the largest and smallest city sizes, an increase of 13 percent. The increase in annual costs from the 1,070,000 city to the 323,000 or 212,000 city is about 2 percent, and to the 132,000 city about 4 percent.

The conclusion of practical import that seems to follow from Table 104 is that when city size reaches a population range of about 130,000, it achieves a level of unit capital costs for incremental industry infrastructure beyond which cost differences are of insignificant value. Relative differences in unit annual costs are somewhat more, but for an eightfold difference in city size (132,000 to 1,070,000) amount to only about Rs. 5 per Rs. 1,000 value added.

It is pertinent to examine the variations in capital and annual costs separately for industrial and residential areas by city sizes, presented by type of facility in Table 105. A summary statement of these costs is provided by Table 106.

Industrial area costs, which cover direct industry requirements, range between 24 and 27 percent of the total unit capital costs in different city sizes. This is a conclusion of significance, having direct implications on priorities of public investment. Highest direct industry costs per Rs. 1,000 value added are observed for the smallest size city, 48,000 population, while the largest city size is the most economic in terms of unit costs for direct industrial infrastructure. Unit capital costs for industry are 13 percent higher in the smallest than in the largest city size, and annual costs, 24 percent higher. The largest reduction in unit capital costs for industry is from city size 212,000 to city size 323,000, in contrast to the pattern for total capital costs. The decline for annual costs is more regular.

Decreasing unit capital costs for direct industrial infrastructure with increasing city size are associated with economies in water and power

Table 105

TOTAL CAPITAL AND TOTAL ANNUAL* COSTS BY INDUSTRIAL AND RESIDENTIAL AREAS
(Rs. 000, Bareilly 1967)

Area and Facility	Total Capital Costs City A	B	C	D	E	Total Annual Costs City A	B	C	D	E
Industrial area										
Site development, excl. roads	348	960	1,223	2,215	8,732	36	100	128	232	914
Roads†	201	436	587	983	3,740	27	61	82	143	545
Rail	90	316	635	604	2,684	10	33	68	65	287
Power‡	728	2,034	2,513	4,477	16,606	108	275	336	588	2,162
Water§	148	391	481	753	2,869	38	93	109	139	516
Sewerage§	149	384	474	898	2,815	16	41	50	95	298
Telephones†	**	**	**	**	**	4	10	14	24	95
Fire†	1	3	4	4	17	1	3	4	6	23
Police†	5	13	17	30	121	2	6	7	13	53
Refuse†	**	**	**	**	**	9	27	31	54	215
Subtotal industrial area	1,670	4,537	5,934	9,964	37,584	251	649	829	1,359	5,108
Residential area										
Site development, excl. roads	286	791	1,027	1,818	7,198	30	84	109	193	765
Roads†	342	1,001	1,257	2,133	8,837	46	136	170	291	1,208
Power‡	440	1,225	1,575	2,779	10,828	64	164	207	360	1,387
Water§	276	714	865	1,826	6,922	71	171	195	338	1,244
Sewerage§	288	667	886	1,687	5,584	31	70	94	179	591
Houses	1,744	4,849	6,306	11,174	51,325	202	562	731	1,295	5,946
Schools	768	2,139	2,774	4,923	19,479	197	552	717	1,270	5,024
Hospitals	735	1,184	1,454	2,899	7,142	158	286	347	726	2,155
Telephones†	**	**	**	**	**	6	18	23	41	162
Fire†	2	5	6	7	28	2	5	6	10	40
Police†	8	23	29	52	205	4	10	13	23	91
Refuse†	**	**	**	**	**	14	45	52	93	367
Subtotal residential area	4,889	12,598	16,179	29,298	117,548	825	2,103	2,664	4,819	18,980
Total costs	6,556	17,135	22,115	39,263	155,129	1,075	2,752	3,492	6,177	24,086

Note: Detail may not add to totals due to rounding.

* At 10 percent interest.
† Cost of serving both areas divided by industrial and residential acreage.
‡ Cost of serving both areas divided by industrial and residential kva.
§ Cost of serving both areas divided by industrial and residential mgd.
** Capital cost not included.

Table 106

TOTAL CAPITAL AND TOTAL ANNUAL COSTS OF INFRASTRUCTURE
FOR INDUSTRIAL AND RESIDENTIAL AREAS
PER RS. 1,000 VALUE ADDED AND PER EMPLOYEE
(Rupees)

		Costs per Rs. 1,000 Value Added				Costs per Employee			
		Industrial		Residential		Industrial		Residential	
	City Size	Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual
A	48,000	224	34	658	111	882	133	2,587	436
B	132,000	220	31	610	102	864	124	2,400	401
C	212,000	221	31	602	99	869	121	2,369	390
D	323,000	209	29	615	101	824	112	2,421	398
E	1,070,000	199	27	623	101	785	107	2,454	396

and to some extent in road costs. Unit rail costs are highest for the median city. In case of other facilities, cost differences are of no significance.

In case of social infrastructure, represented by residential area costs, unit capital costs assume a U-shaped function. Most of the drop in social infrastructure costs from the 48,000 to the 132,000 city is attributable to the decrease in unit hospital costs observed in Table 100, occasioned by economies of scale. Hospital costs decline further for the largest city. As against this, unit housing costs increase sharply for the largest city as a result of the need for multistory buildings. In terms of annual costs, presented in Table 106, unit costs for social infrastructure fall by 8 percent from the 48,000 to the 132,000 city. Therefore, changes in unit annual costs for the various social infrastructure facilities largely offset each other.

The conclusion that unit capital or annual costs do not increase beyond a certain population size should be viewed within the framework of the cost elements analyzed and sizes of cities studied. Even within this scope, the conclusion offers policy implications for investment which we discuss in Chapter VII.

VI EFFECTS OF CHANGES IN INDUSTRY MIX AND OTHER VARIABLES ON UNIT COSTS

Here we allow for changes in a number of factors that were kept constant in the preceding chapter to provide a clearcut picture of cost influences related to city size. Industry mixes realistically oriented to the locational advantages of small cities and of large cities are first studied for their impact on infrastructure costs. Resulting changes in the unit costs of specific facilities like power and water are also examined. The influence of land costs and alternative interest rates is measured. The final section of the chapter considers possible effects on costs of a change in the size of industry mix, secondary employment, alternative assumptions on housing costs, density, and congestion.

Costs for Industry Mixes Oriented to Small and Large Cities

The modus operandi for the second test of the research hypothesis is to establish industrial mixes directly relatable to small and large cities, based on the industry sets given in Table 79. The combinations of sets envisaged are:

1. Ubiquitous and small city oriented industries for small city mix

2. Ubiquitous, medium, and large city oriented industries for large city mix

In combining the industry sets, judgment was applied to the different proportions or weights needed to be assigned to individual industries. Specific considerations were that:

1. The production level of each industry should be commensurate with city size, judged in terms of interindustry and forward linkages and demand sources.

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* The genesis of this approach is that certain manufacturing operations because of their locational and infrastructure characteristics are appropriate for different city sizes. Pursuant to this, we formed a typical small city mix consisting of industries like crushers and expellers, small castings, paper board and straw board, and fruit and vegetable canning. Industries of the types shown in List D of Table 79, having more complex manufacturing and marketing requirements, were included in the typical large city mix. Value added per employee for the small city was substantially lower than for the typical large city mix.

2. The shares of large and small city industries in the respective mixes should remain appreciable in order to reflect the typical infrastructure characteristics of those size cities, rather than be influenced by combinations of industries oriented to other city sizes.

City size characterization in the industrial mixes costed in the first and second tests is revealed if we examine the respective shares of city size oriented industries in the different mix compositions. Table 107 gives relevant data for the three typical mixes. It is seen from this table that in the large city oriented mix, 51 percent of the output value is envisioned to be added by industries belonging to List D, which are large city based. In the median or proportionate mix, 73 percent of the projected incremental value added is expected to be the share of industries oriented to medium size cities. Some 46 percent of the value added is envisaged to be the contribution of small city oriented industries in the typical small city mix. Thus, as may be seen, the typical city size mixes maintain their character.

Table 107

VALUE ADDED SHARE OF INDUSTRIES ORIENTED TO DIFFERENT CITY SIZE IN TYPICAL INDUSTRY MIXES
(Rs. 000)

Combination of Industry Sets	Small City Mix		Proportionate Mix		Large City Mix	
	Value Added	Percent of Total	Value Added	Percent of Total	Value Added	Percent of Total
Ubiquitous	4,045	54.4%	6,035	22.5%	43,990	23.3%
Small city	1,391	18.8	--	--	--	--
Unspecified small	1,993	26.8	--	--	--	--
Medium city	--	--	19,524	72.7	47,904	25.4
Unspecified medium	--	--	1,309	4.8	--	--
Large city	--	--	--	--	96,876	51.3
Total	7,430	100.0%	26,870	100.0%	188,770	100.0%

Infrastructure requirements for the typical small and large city mixes developed on the basis of the above procedures are summarized in Table 108. This table provides material for the second test of the hypothesis. It is interesting to examine the characteristics of the small and large city oriented mixes in view of our preceding analysis. Several observations can be made on the city size peculiarities reflected in the respective mixes. One effective way of bringing these out is to examine their gross infrastructure requirements, expressed as coefficients per Rs. 1,000 value added.

INFRASTRUCTURE REQUIREMENTS IN NEW OR EXPANDED FACTORIES OF TYPICAL MIXES FOR SMALL AND LARGE CITIES

Value Added and Requirements	Small City	Large City
Value added (Rs. 1000)	7,430	188,770
Employment (number of workers)	2,950	45,458
Floor space (000 sq ft)	737	7,193
Storage space (000 sq ft)	731	1,715
Connected load (kw)	2,315	38,962
Power consumption (kwh)	5,401	56,453
Water consumption (gpd)	1,354,927	3,392,883
Transport - road (tons)	59,803	507,992
- rail (tons)	38,018	526,492

Table 109, which gives these coefficients, shows clearly the bias of typical small city mix for labor intensive industries and greater physical input requirements per unit of value added. Specifically, the small city mix suggests a much higher level of water consumption, which is on account of typical orientation of industries whose intensity of water use is high. Comparison of Tables 85 and 109, which give infrastructure coefficients for the typical city size industry mixes, shows that (1) labor requirements, floor space, power and water consumption, and tonnage per unit of value added are far greater for the small city mix than for the median or proportionate mix discussed and costed in Chapter V; and (2) labor requirements for the large city mix are slightly lower per unit of value added, floor space and transport requirements are substantially lower, and power and water requirements are greater compared to the proportionate mix. These features of mixes oriented to different size cities are in conformity with the locational and infrastructure attributes of industries.

Table 109

INFRASTRUCTURE REQUIREMENTS OF SMALL AND LARGE CITY MIXES PER RS. 1,000 VALUE ADDED

Requirements	City Size, 1967	
	48,000	1,070,000
Employment (number of workers)	.397	.241
Floor space (sq ft)	99	38
Storage space (sq ft)	98	9
Connected load (kw)	.312	.206
Power consumption (kwh)	727	299
Water consumption (gpd)	182	18
Transport - road (tons)	8.05	2.69
- rail (tons)	4.71	2.79
- total (tons)	12.76	5.48

By changing the composition of mixes, we have removed the assumption of a proportional relationship between value added, employees, and infrastructure requirements in industrial increments for cities of different size. We refer to this as a two variable test, because the industry mix as well as the size of city varies in the comparisons which follow. First, we translate the typical industry mix requirements into gross physical requirements on the same assumptions, standards, and design criteria as adopted for the first test. On-site requirements for typical industry mixes for city A and city E are given in Table 110. Requirements of the proportionate mix for city C are also presented in the table. Sites selected for the first test are disposed to acreage adjustments in either direction, and are suitable for the new mixes. In the case of the typical small city mix for which the gross industrial and residential area requirements have increased substantially, the same sites are amenable to physical extension toward the southwest. The gross site areas for the large city decline but do not necessitate any change in the selected sites, either for industrial or residential areas. As for off-site requirements of power station capacity, sewer outfall, and sewage disposal, these change with the change in infrastructure requirements.

Unit costs of infrastructure applied to the requirements are again drawn from Chapter III. Capital and annual costs thus derived from small, median, and large city industry mixes are given in Table 111.

It is seen from Table 111 that off-site capital costs have a small share in the total costs of infrastructure, ranging from 4.1 percent for the largest city to 7.3 percent for the smallest city. Among the various off-site cost elements, the most important are sewerage for the smallest city size with 3.9 percent of the total capital costs, and power in the median size city accounting for 2.5 percent.

The percentage distribution of costs among the various facilities is seen in Table 112. Housing is the single most significant cost element in all city sizes, with nearly 24 percent of the total capital cost in city size A, 29 percent in city size C, and 34 percent in city size E. Power, water, and site development are other important cost elements, totalling over 30 percent of the total capital cost in each size city.

When these cost elements are examined separately for industrial and residential areas, in Table 113, it is noted that direct industrial infrastructure varies from nearly 23 percent of total capital costs in city size 1,070,000 to about 38 percent in city size 48,000. This share is about 27 percent for the median city. The sharp increase in the share of direct industrial costs in the small city reflects the high levels of physical inputs required for industries in the small city mix, relative both to value added and to employment. The costs of elements designed to serve both industrial and residential areas have been allocated on the basis of acreage or volume of supply, as indicated in Table 113. Among the direct industrial costs, power is the single most important element. When water costs are prorated on the basis of industrial and housing consumptions, water is the second most important direct industrial cost element for the small city. For the median and large city, site development is the second important cost category.

Table 110

ON-SITE INFRASTRUCTURE REQUIREMENTS FOR INDUSTRY MIXES ORIENTED TO THREE SIZE CITIES

	City		
	A	C	E
Population (000)	48	212	1,070
Industrial area			
Gross area (acres)	72	116	706
Power			
Load capacity (kva)*	2,572	4,711	43,291
Rail			
On-site tonnage terminating by rail (000 tons)	18.4	53.4	276.4
No. of cars per day	3.0	9.0	46.0
No. of cars at goods siding	2.0	6.0	29.0
Length of goods siding (ft)	60	180	870
Sewerage			
Sewage flow (mgd)	1.26	0.46	3.69
(cfs @ 90% water supplied)	(2.34)	(0.85)	(6.85)
Design peak (mgd)	3.78	1.38	11.07
(cfs @ 3 x DWF)	(7.80)	(2.60)	(20.55)
Size of outfall sewer (diameter in in.)†	‡	15§	
Residential area			
No. of industrial workers to be housed	2,655	6,147	40,912
Gross area (acres)	88.5	205.0	1,364.0
Housing area population (000)	13.3	30.7	204.6
Dwelling units			
No. of dwellings to be costed	531	1,229	8,182
Power			
Load capacity (kva)*	328	759	5,051
Sewerage			
Sewage flow (mgd)	.32	0.74	6.54
@ 80% water supplied (cfs)	(.59)	(1.37)	(12.14)
Design peak (mgd)	.96	2.22	19.62
3 times DWF (cfs)	(1.77)	(4.11)	(36.42)
Size of outfall sewer (diameter in in.)†	12‡	16‡	
Schools			
Schoolgoing children			
Primary	1,486	3,440	22,910
Higher secondary	1,155	2,670	17,797
Hospitals			
Number of hospital beds	40	60	409

Table 110 (concluded)

	City		
	A	C	E
Serving both areas			
Water			
Industrial			
Water for industry use (000 gpd)	1,355	406	3,393
Additional (000 gpd)	44	103	682
Total industrial use (mgd)	1.4	.51	4.1
Residential			
Water required @ 30 gpcd (mgd)	.40	.92	8.18††
Total gallons per hour (000)	208.2	140.4	1,191.8
Total OHT capacity (000) gal)	416	281	2,383

Note: Requirements based on norms developed by analysis of India field data in Chapter III. See corresponding sections in Chapters III and V for details.

* Power factor assumed at 0.9.
† Manning's formula: n = 0.
‡ Since outfall sewer has been combined for both areas, no section size separately for industrial area is shown.
§ Outfall sewer later to be combined for flow from both areas; section size is for this area flow only.
** Calculated by Rational Method.
†† @ 40 gpcd.

Table 111

COSTS OF FACILITIES BY INDUSTRY MIX
(Rs. 000, Bareilly 1967)

Area and Facility	Small City Mix				Proportionate Mix, City C				Large City Mix			
	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost	Capital Cost	Annual Capital Cost*	AMO	Total Annual Cost
ON-SITE												
Industrial area												
Site development, excl roads	759	76	3	79	1,223	123	5	128	7,415	750	29	779
Roads	284	35	6	41	458	56	10	66	2,784	340	60	400
Rail	83	9	†	9	355	37	†	37	1,191	125	†	125
Power	1,264	135	40	174	2,037	217	56	273	12,398	1,321	301	1,622
Sewerage	202	20	1	21	325	33	2	34	1,980	198	10	208
Subtotal	2,593	275	50	324	4,398	466	72	538	25,798	2,734	400	3,134
Residential area												
Site development, excl. roads	443	44	2	47	1,027	104	5	109	6,832	690	36	726
Roads	520	63	8	71	1,204	147	17	164	8,014	977	116	1,093
Power	646	67	20	88	1,497	156	41	197	9,959	1,039	241	1,280
Sewerage	279	28	1	29	646	65	3	68	4,297	431	21	452
Houses	2,719	274	41	315	6,306	636	95	731	48,706	4,912	731	5 643
Schools	1,200	129	179	308	2,774	298	420	717	18,488	1,983	2,788	4,770
Hospitals	903	92	120	212	1 454	148	199	347	7,019	717	1,227	1,944
Subtotal	6,710	698	372	1,070	14,908	1,553	780	2,333	103,314	10,748	5,160	15,908
Serving both areas												
Water	1,345	137	181	319	1,346	138	166	304	9,831	1,005	759	1,764
Total on-site	10,647	1,110	603	1,713	20,653	2,156	1,018	3,174	138,943	14,486	6,319	20,806
OFF-SITE												
Industrial area												
Roads	71	8	negl	8	129	15	1	16	276	45	14	58
Rail	7	1	†	1	280	31	†	31	714	79	†	79
Subtotal	78	9	negl.	9	409	46	1	47	1,090	123	11	137
Residential area												
Roads	7	1	negl	1	53	6	—	6	228	27	—	27
Sewerage	22	2	negl	2								
Subtotal	30	3	negl.	4	53	6	—	6	228	27	—	27
Serving both areas												
Roads									265	32	13	46
Power	278	29	9	38	554	56	15	73	2,401	252	58	310
Sewerage	427	44	2	46	389	40	2	42	1,550	161	8	168
Telephones	‡	‡	16	16	‡	‡	37	37	‡	‡	214	214
Fire	4	1	13	14	10	2	8	10	43	7	205	212
Police	20	2	8	10	46	5	16	20	309	31	101	133
Refuse	‡	‡	36	36	‡	‡	83	83	‡	‡	552	552
Subtotal	729	76	81	159	1,000	104	160	265	4,568	483	1,181	1,664
Total off-site	836	88	84	172	1,462	156	161	318	5,886	633	1,195	1,829
Total	11,483	1,198	687	1,885	22,115	2,312	1,180	3,492	144,829	15,121	7,514	22,635
Percentage												
On-site	92 7%	92.7%	87 8%	90.9%	93.4%	93.3%	86.3%	90 9%	95.9%	95.8%	84.1%	91.9%
Off-site	7.3	7.3	12.2	9.1	6.6	6.7	13.7	9.1	4.1	4.2	15.9	8.1

Note: Detail may not add to totals due to rounding
negl = negligible, less than Rs. 500.

* Annual capital cost @ 10 percent interest
† AMO assumed by railway
‡ Capital cost not included

Table 112

ANNUAL COSTS BY INDUSTRY MIX AND BY FACILITY
Annual Capital, AMO, Total Annual, Percentage Distribution
(Rs. 000, Bareilly 1967)

	Annual Capital Costs*			Annual Maintenance and Operation			Total Annual Costs			Total Annual Costs Percentage Distribution		
	Small	C	Large	Small	C	Large	Small	C	Large	Small	C	Large
Site Development, Excl. Roads	120	227	1,440	5	10	65	126	237	1,505	6.7%	6.8%	6.6%
Roads	107	224	1,421	14	28	203	121	252	1,624	6.4	7.2	7.2
Rail	10	68	204	†	†	†	10	68	204	0.5	1.9	0.9
Power	231	431	2,612	69	112	600	300	543	3,212	15.9	15.6	14.2
Water	137	138	1,005	181	166	759	319	304	1,764	17.0	8.7	7.8
Sewerage	94	138	790	4	7	39	98	144	828	5.2	4.1	3.7
Houses	274	636	4,912	41	95	731	315	731	5,643	16.8	20.9	24.9
Schools	129	298	1,983	179	420	2,788	308	717	4,770	16.4	20.5	21.1
Hospitals	92	148	717	120	199	1,227	212	347	1,944	11.2	9.9	8.6
Telephones	‡	‡	‡	16	37	244	16	37	244	0.8	1.1	1.1
Fire	1	2	7	13	8	205	14	10	212	0.7	0.3	0.9
Police	2	5	31	8	16	101	10	20	133	0.5	0.6	0.6
Refuse	‡	‡	‡	36	83	552	36	83	552	1.9	2.4	2.4
Total	1,198	2,312	15,121	687	1,180	7,514	1,885	3,492	22,635	100.0%	100.0%	100.0%

Note: Detail may not add due to rounding.

* Annual capital cost @ 10 percent interest.
† AMO assumed by railway.
‡ Capital cost not included.

Table 113

TOTAL CAPITAL AND TOTAL ANNUAL* COSTS BY
INDUSTRY MIX, INDUSTRIAL AND RESIDENTIAL AREAS
(Rs. 000, Bareilly 1967)

Area and Facility	Total Capital Costs			Total Annual Costs*		
	Small	C	Large	Small	C	Large
Industrial area						
Site development, excl. roads	759	1,223	7,445	79	128	779
Roads†	355	587	3,258	49	82	475
Rail	91	635	1,905	10	68	204
Power‡	1,511	2,513	14,549	208	336	1,900
Water§	1,046	481	3,284	248	109	589
Sewerage§	542	474	2,540	58	50	269
Telephones†	**	**	**	7	14	83
Fire†	2	4	15	6	4	72
Police†	9	17	105	5	7	45
Refuse†	**	**	**	16	31	188
Subtotal industrial area	4,315	5,934	33,101	686	829	4,604
Residential area						
Site development, excl. roads	443	1,027	6,832	47	109	726
Roads†	527	1,257	8,409	72	170	1,149
Power‡	677	1,575	10,209	92	207	1,312
Water§	299	865	6,547	71	195	1,175
Sewerage§	388	886	5,287	40	94	559
Houses	2,719	6,306	48,706	315	731	5,643
Schools	1,200	2,774	18,488	308	717	4,770
Hospitals	903	1,454	7,019	212	347	1,944
Telephones†	**	**	**	9	23	161
Fire†	2	6	28	8	6	140
Police†	11	29	204	5	13	88
Refuse†	**	**	**	20	52	364
Subtotal residential area	7,169	16,179	111,729	1,199	2,664	18,031
Total costs	11,483	22,115	144,829	1,885	3,492	22,635

* Annual capital cost @ 10 percent interest.
† Costs of serving both areas divided by industrial and residential acreage.
‡ Costs of serving both areas divided by industrial and residential kva.
§ Serving both areas divided by industrial and residential mgd.
** Capital cost not included

Results of Second Test

Capital and annual costs per Rs. 1,000 value added and per employee are shown in Table 114 for the second test of the hypothesis. An interesting feature of this test is its comparison between (1) a typically oriented small city mix which characteristically is labor intensive with low value added per employee, (2) diversified median mix, and (3) a typical large city mix with low labor inputs per Rs. 1,000 value added. As noted, this test shows cost behavior when the composition of mix is changed to suit the locational characteristics of city sizes. The size of increment in terms of value added has been kept the same as for the first test.

Table 114

CAPITAL AND ANNUAL COSTS OF INFRASTRUCTURE PER RS. 1,000 VALUE ADDED AND PER EMPLOYEE FOR INDUSTRY MIXES ORIENTED TO THREE SIZE CITIES

City Size		Cost per Rs. 1,000 Value Added		Cost per Employee	
		Capital	Annual	Capital	Annual
A	48,000	1,546	254	3,893	639
C	212,000	823	130	3,238	511
E	1,070,000	767	120	3,183	498

Table 114 shows that unit capital and annual costs decline with the increase in city size and change in composition of mix. Comparison with Table 104 shows that for the less space-intensive and slightly less labor-intensive set of industries, unit costs of infrastructure in the largest city are somewhat less. This means that while substantial scale economies are achieved with the increase in the level of infrastructure requirements, no overall diseconomies become apparent, at least until the city population size 1,070,000. However, the sharp decline in unit costs which is apparent between city sizes A and C tapers off somewhat between city sizes C and E. This may be seen from the fact that the unit capital costs in city size 48,000 are more than double those of city size 1,070,000, or about 102 percent, whereas for city size 212,000, the increase over the largest city is only 7 percent. Differences in unit annual costs follow the same pattern, slightly accentuated.

On account of different characteristics and composition of the mixes, aggregate value added per employee is of different magnitude in case of these three city-size mixes. As derived from Table 84 and Table 108, value added per employee for the small city mix is Rs. 2,519, for the median mix Rs. 3,933, and for the large city mix Rs. 4,153. It was stressed in Chapter IV that such differences result from product and process differences

among industries, not differences in productivity. In order not to overemphasize the cost difference in terms of value added, it is useful to examine unit capital and annual costs per employee. These are seen in Table 114.

It is noted from the table that unit costs per employee vary in a much smaller proportion among the three size cities than when observed in terms of value added. Unit capital costs per employee in the small city are about 22 percent above those in the large city. In annual costs, the difference is about 28 percent. Again, while unit costs show a wide difference between city sizes A and C, variations between city C and E are of much less significance.

Table 115 gives the unit capital and annual costs for city sizes A, C, and E, by industrial and residential areas.

Table 115

CAPITAL AND ANNUAL COSTS FOR INDUSTRIAL AND RESIDENTIAL AREAS PER RS. 1,000 VALUE ADDED AND PER EMPLOYEE

		Cost per Rs. 1,000 Value Added				Cost per Employee			
		Industrial		Residential		Industrial		Residential	
City Size		Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual
A	48,000	581	92	965	161	1,462	233	2,430	406
C	212,000	221	31	602	99	869	121	2,369	390
E	1,070,000	175	24	592	96	728	101	1,456	396

Two significant observations on this table are made. First, it is seen that unit capital costs for industry fall much more sharply than for residential areas with increase in city size and change in industry mix. Table 115 shows a decline of Rs. 406 per Rs. 1,000 value added in unit capital costs for industry, compared to Rs. 373 for residential area. This is in spite of the fact that the residential area accounts for over 60 percent of the total infrastructure capital costs. Second, per employee unit capital costs for residential area are higher for the largest city size, compared to city sizes A and C. This is explained primarily by the need for multiple story housing in the largest city. The increase in unit costs for residential areas, however, is much smaller than the decline in direct industrial costs.

This concludes our second test of the effects of city size on costs of industry infrastructure. It is shown that when the composition of industry mix is changed to suit the locational characteristics of different

sized cities, the unit cost differences between cities become sharper. The fall in unit costs is greatest from the small to the medium city, related to very wide differences in the infrastructure requirements of the small city mix and the diversified or proportionate mix. Between the medium and largest cities, the difference in unit costs is much less pronounced, but is also related to differences in types of industry with size of city.

Costs of Individual Infrastructure Facilities

It is to be noted that scale economies for certain infrastructure facilities are more pronounced for the typical small city mix than for the proportionate mix when both are costed for the smallest city. Variations in unit costs of water, for instance, can be observed in Table 116. For the smallest city, the higher requirements of the small city mix bring about a reduction in unit costs to Rs. 563 per million gallons, compared to Rs. 797 for the proportionate mix. Changes in unit costs for the proportionate mix with increase in the size of mix in larger cities are also apparent in Table 116.

Table 116

ANNUAL UNIT COSTS OF WATER SUPPLY
BY INDUSTRY MIX AND CITY SIZE

Industry Mix and City	Total Annual Cost (Rs.)	Annual Requirement (mg)	Cost per mg (Rs.)
Proportionate Industry Mix for City A	109,192	137	797
Proportionate Industry Mix for City B	263,553	376	701
Proportionate Industry Mix for City C	303,891	489	622
Proportionate Industry Mix for City D	477,098	1,066	448
Proportionate Industry Mix for City E	1,760,183	4,217	417
Small City Mix - city A	318,617	566	563
Large City Mix - city E	1,764,159	4,216	418

In the case of power, for which unit costs are shown in Table 117, these differences are more pronounced for the large city mix, which has greater power requirements. In city E, the cost of distribution per installed kva of capacity for the large city mix is Rs. 66, compared to Rs. 92 for the proportionate mix.

Table 117

ANNUAL UNIT COSTS OF POWER DISTRIBUTION CAPACITY
BY INDUSTRY MIX AND CITY SIZE

Industry Mix and City	Total Annual Cost (000 Rs.)	Requirement (kva)	Distribution Cost per kva (Rs.)
Proportionate Industry Mix for City A	172	1,510	114
Proportionate Industry Mix for City B	439	4,205	104
Proportionate Industry Mix for City C	543	5,470	99
Proportionate Industry Mix for City D	948	9,711	98
Proportionate Industry Mix for City E	3,549	38,433	92
Small City Mix - city A	300	2,900	103
Large City Mix - city E	3,212	48,342	66

These economies are shared by the residential area also, as seen in the reduction in residential area capital cost for the smallest city from Rs. 2,587 for the proportionate mix reflected in Table 106 to Rs. 2,430 for the typical small city mix covered in Table 115. No difference in residential area cost occurs, however, with change in industrial mix in the largest city.

Thus, particularly in the case of the smallest city, the cost study provides clear evidence that on a unit basis, costs of certain infrastructure facilities for mixes oriented to city size are much lower and the investment is more economical than for industries located without orientation to city size.

Influence of Land Costs

Costs of land have been kept apart from our estimates, as stated previously, so that infrastructure cost comparisons can be made without the effect of local variations in land prices. A glance at prevailing land prices for the sites identified in each test city, shown in Table 118, confirms the necessity of examining land costs separately. Reported land prices, based on information as to recent sales of comparable parcels in the vicinity of the chosen site, vary greatly from city to city. Purely local factors are influential in current land prices. For the five test cities, these bear no meaningful relationship to size of city. The highest quotation is in the smallest city A, cities B and E are on par, while cities C and D are in the lowest range.

Table 118

COSTS OF LAND

City Size		Land Type	Site Cost (Rs./acre)
A	48,000		64,000
B	132,000	Industrial	31,460
		Residential	43,560
C	212,000		16,940
D	323,000		14,520
E	1,070,000	Industrial	31,460
		Residential	43,560

Source: Field survey.

Table 119 compares total land costs for each city, based on reported prices per acre and total required acreage, with the capital costs of infrastructure, based on the first test. As a share of the total costs of development, land costs vary from around 17-20 percent in cities D and C to a high of 47 percent in city A. Land would amount to 36 percent of total development cost in cities B and E.

Table 119

COSTS OF INFRASTRUCTURE AND LAND IN FIVE TEST CITIES
(Rs. 1,000)

City Size		Capital Costs of Infrastructure	Costs of Land	Total	Percent of Total	
					Infrastructure	Land
A	48,000	6,566	5,760	12,316	53%	47%
B	132,000	17,135	9,745	26,880	64	36
C	212,000	22,115	5,438	27,553	80	20
D	323,000	39,263	8,320	47,583	83	17
E	1,070,000	155,129	88,645	243,774	64	36

Land costs of this magnitude obviously have an important impact on the process of equipping urban areas for new industry. The implications of high land prices for policies of urban land acquisition and taxation are beyond the scope of this study. The need for research focused on these questions is evident from the impact of land costs on the total costs of infrastructure.

Influence of Alternative Interest Rates

As stated earlier, calculation of annual capital cost equivalents for all estimates in this and the preceding chapter is based on the formula for capital recovery factors at 10 percent interest. This is closer to the realistic opportunity cost of capital in developing economies than the 5 percent rate characteristic of municipal and other public agency bookkeeping interest rates. In order to quantify the difference in total and relative infrastructure costs for 10 percent and 5 percent interest rates, Table 120 is presented. Calculations for this table are based on the same assumptions on service life for each class of facility as were made for earlier estimates, applying the respective capital recovery factors for each period of service life at 5 percent rather than 10 percent interest. Annual maintenance and operation costs are unchanged.*

As compared to calculation at 5 percent interest, total annual costs of infrastructure by the previous calculation at 10 percent interest are 37 percent higher in the smallest city and 40 percent higher in the largest city. The absolute increase is Rs. 290,000 for the city of 48,000 population and Rs. 6,858,000 for the 1,070,000 city. The significance of these differences is seen more clearly when expressed per Rs. 1,000 value added. Annual costs per Rs. 1,000 value added in city A, as shown in Table 120, increase from about Rs. 106 at 5 percent interest to about Rs. 145 at 10 percent interest. Corresponding costs in city E are about Rs. 91 and Rs. 128. The cost difference which results from using a realistic as opposed to a bookkeeping cost of capital is thus Rs. 37 to Rs. 39 per Rs. 1,000 value added.

However, relationships in unit costs as a function of a city size are not markedly changed. At the 5 percent interest rate, total annual costs for city A are 15.8 percent above those for city E, compared to the 13.4 percent reported earlier for the 10 percent rate. The difference is, of course, explained by the steeper fall in AMO costs compared to capital costs in the total infrastructure package. The implication is that if capital were judged to have an opportunity cost higher than 10 percent--say 15 percent--cost differences associated with city size would decrease in relative terms, although absolute rupee differences would be greater.

Evaluation of Other Cost Variables and Assumptions

In order to build a reliable total estimate of those costs and cost determinants that are central to the issue of city size and can be analyzed with firm data, the scope of research was defined in Chapter II to exclude

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* In investment planning, a change of this order in costs of capital could well induce changes in design in order to minimize the combined costs of installation, operation, and maintenance. Such modifications are important in planning new or expanded facilities, but are at a level of detail that is not meaningful for the present overall cost comparison.

Table 120

COMPARISON OF ANNUAL COSTS OF INFRASTRUCTURE AT 5 AND 10 PERCENT INTEREST

	City				
	A	B	C	D	E
Total capital costs (Rs. 000)	6,556	17,135	22,115	39,263	155,129
Annual capital costs (Rs. 000)					
@ 10% interest	684	1,791	2,312	4,101	16,203
@ 5% interest	394	1,035	1,336	2,365	9,345
Annual maintenance and operation costs (Rs. 000)	391	961	1,180	2,076	7,883
Total annual costs (Rs. 000)					
@ 10% interest	1,075	2,752	3,492	6,177	24,086
@ 5% interest	785	1,996	2,516	4,441	17,228
Total annual costs per Rs. 1,000 value added					
@ 10% interest	144.7	133.2	130.0	129.6	127.6
@ 5% interest	105.7	96.6	93.6	93.2	91.3
Percent of annual capital costs to total annual costs					
@ 10% interest	63.6%	65.1%	66.2%	66.4%	67.3%
@ 5% interest	50.2	51.9	53.1	53.3	54.2

variables that are difficult to quantify, such as the effects of secondary or induced employment, varying residential densities, and congestion. Furthermore, in order to make clearcut estimates of incremental costs as related to city size, specific assumptions were made with respect to size of industry mix and the proportion of employees to be housed with public funds. These factors must now be briefly examined.

Size of Industry Mix and Secondary or Multiplier Effects

Projections of Indian industrial growth substantially below those available as a basis for estimating the volume of incremental industry in Chapter V have subsequently been made, both by the Planning Commission* and by independent research authorities.† Other things being equal, the main effect of a smaller industry mix on the cost estimates of this report would be with respect to the size of city for which the decline in costs begins to flatten out. Depending on the size of reduction, the decrease in unit costs might taper off for cities in the vicinity of 200,000 population, instead of the population range around 130,000.

Multiplier effects of new industry in creating or inducing additional demand for locally produced goods and services, stimulating secondary and further increases in employment and demand, would have the opposite result, shifting the unit infrastructure cost curve to the left. The size, composition, and income distribution of newly induced activities would have to be assessed to estimate unit cost effects, but at a minimum, the increased employment and resulting social infrastructure demands would result in an earlier reduction of unit hospital costs in the 50,000-130,000 city size range, an earlier increase in per capita water requirements in the 300,000 city size vicinity, and an earlier rise in housing costs in the largest cities.

Taken together, the combined result of meeting the needs of a smaller industry mix but providing also for multiplier effects would probably be to maintain the relationship of unit costs to city size more or less the same as in the principal test of the hypothesis. This broad conclusion can of course be tested for any particular set of industries and estimate of induced effects, with the aid of cost and requirements data presented in Chapters III and IV.

Costs of Industrial Housing

The weight of housing in infrastructure costs is so great that any marked change in the estimate and assumption which led to the inclusion in costs of 20 percent of incremental urban industrial housing would

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* Government of India, Planning Commission, Approach to the Fourth Five-Year Plan, New Delhi, May 1968, 33 pp.

† See footnote, p. 269.

drastically alter the total and unit cost profiles. As noted, the 20 percent estimate is an approximation based on current programs that provide public subsidies and grants for industrial housing, on the assumption that this level of support will continue. It has been argued, however, that infrastructure should instead be costed on the assumption of no public funding of industrial housing, first on the ground that this definition of infrastructure corresponds more closely to direct industry needs, second on the ground that under existing budget constraints, the housing standards sought by public authorities are unrealistically high in comparison with prevailing housing conditions in either urban or rural India. On the other hand, the argument has also been advanced that 100 percent of incremental housing for urban industrial employees should be included in the cost estimate. If costs of housing increase with city size, this is a real cost disadvantage to society whether publicly or privately financed. As would be expected from the data on housing costs already presented, these two approaches lead to diametrically opposite cost conclusions.

The effect of alternative assumptions with respect to levels of industrial housing is summarized in Table 121, in terms of annual infrastructure costs per new industrial employee.

Table 121

ANNUAL INFRASTRUCTURE COSTS PER EMPLOYEE
FOR ALTERNATIVE HOUSING LEVELS
(Rupees)

City Size		Percentage of New Urban Industrial Housing Included in the Cost Estimates			
		0%	20%	40%	100%
A	48,000	462	569	676	996
B	132,000	417	524	631	952
C	212,000	404	511	618	939
D	323,000	403	511	618	939
E	1,070,000	379	503	627	999

Exclusion of all new industrial housing would result in unit infrastructure costs that continue to decline substantially with city size through the largest city studied. On the zero percentage assumption, costs per employee in the smallest city are 22 percent above those in the largest city, compared to the 13 percent difference calculated on the original assumption. If 100 percent housing of new urban industrial employees is included, on the other hand, diseconomies of large city size become pronounced. On the 100 percentage assumption, costs per employee in the largest city are not only 6 percent above those in the next largest city

but are indeed slightly higher than in the smallest city. Costs per employee are also shown in Table 121 on the assumption of 40 percent inclusion of industrial housing. Diseconomies of large city size make their first appearance in this case, with a 1-2 percent increase in unit costs for the largest city instead of the 1-2 percent decrease seen for the 20 percent case.

Interpretation of these conflicting results depends on the standpoint from which they are viewed. Given the focus of this study on costs that must normally be met by public funds in order to equip cities for new industry, we consider the original assumption most realistic. It appears evident that some measure of public financing for industrial housing is required to achieve dwelling conditions in Indian cities that will make for improved health, family life, and industrial productivity. Publicly supported industrial housing observed in the field cities, upon which our cost data are based, is of a minimum adequate standard. Inclusion of 20 percent of housing costs at these standards therefore seems appropriate.

If, on the other hand, the standpoint is that of the full social costs occasioned by the collective effects of city size, cost differences per employee with inclusion of 100 percent housing are the relevant measure.

Density, City Size, and Congestion Costs

We found in Chapter V that differences in density per developed acre among the 18 cities surveyed were not correlated with city size.* No basis existed in the field evidence, therefore, for interpreting variation in density or related costs as a function of city size. In incremental cost estimates, accordingly, gross residential density was held constant for all test cities, although net residential density was increased in the largest city in order to accommodate space requirements other than housing. As a result of keeping gross density constant, the incremental cost estimates

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* This lack of correlation between density and city size is not entirely expected. Two reviewers of the initial report observe from planning experience that density characteristically increases with city size. On the other hand, Hansen has pointed out that in areas of high population concentration, even small cities may have high population density (reference 34, pp. 153 and 155). High density in the older sectors of many medium and small cities in the field region supports this observation. For an analysis of contrasting patterns of density in Western and non-Western cities see Brian J. L. Berry, James W. Simmons, and Robert J. Tennant, "Urban Population Densities: Structure and Change," Geographical Review, Vol. LIII, No. 3, July 1963, pp. 389-405. Also see TEKNE, Consulenze e Progettazioni Tecnico Organizzative, Ricerca sui Costi di Insediamento Urbani ed Industriali in Varie Città d'Italia, Milano, 1962 (multilith), 232 pp.; and Bruce E. Newling, "Urban Growth and Spatial Structure: Mathematical Models and Empirical Evidence," Geographical Review, Vol. LVI, April 1966, pp. 213-225.

provide a clearcut measure of the effects of city size without attempting to take into account the many contrasting density patterns which exist in different cities.

In order to evaluate the cost implications of simultaneous variation in urban size and density, a build-up approach on the following lines would appear necessary. First, the effects of different neighborhood density patterns would be assessed in terms of trade-offs between housing construction costs and costs of distribution and collection facilities under various design and cost conditions. As noted in Chapter II, studies by Stone, Jones, and others illustrate this type of analysis starting at the neighborhood level. Next, cost characteristics of citywide configurations combining neighborhoods of different size and density would require consideration. Sectors or neighborhoods of different densities, resulting in differential loads, influence the location and size of both nodal and lineal facility components. Cost effects to be studied would include trade-offs between unit-miles of required transport and flow in distribution and collection systems, which tend to increase with size of area, and economies of scale primarily in nodal production and treatment facilities.

Total load on city systems is influenced by both size of area and density patterns. For the constant density assumption, it was suggested from examination of off-site costs in Chapter V that scale economies in various facilities more than offset cost increases due to increased city area. The slight decrease in lineal costs per gross acre between the smallest and largest city, but constant relative share of lineal costs at 24 percent of total infrastructure costs, tends to confirm this interpretation. These results, however, disregard the influence of congestion costs. Without an adequate estimate of congestion costs, it is not possible to evaluate the full social costs associated with either city size or density variations.

The study of congestion costs is therefore suggested as a major area for further research. Instead of isolating the question of congestion for separate study, however, it is believed that the complexity and costs of research on this question make it necessary to tackle the issue of congestion costs in cities of developing countries as a well-defined phase of ongoing traffic analyses of the kind normally undertaken for the planning of urban transport systems. As a preparatory step, pilot research and consultation would be desirable in order to establish a common theoretical base and methodology, as part of urban transport studies, for analyzing congestion costs as related to city size. Two dimensions of the present study which influence traffic flows and costs but are not explicitly within the scope of the present research should be considered for inclusion in a common procedure for urban transport studies: (1) measurement and analysis of developed area densities in different city sectors, and (2) measurement and analysis of urban land prices by sector. Data on variations in density and land costs as related to transport systems are extremely limited in cities of the types covered in the present study, but are integrally related and are essential to adequate analysis for the planning of urban facilities.

VII IMPLICATIONS OF THE RESEARCH: INFRASTRUCTURE COSTS AND INVESTMENT DECISIONS

Every research task serves certain expectations. The present research, which bears directly on the efficient use of scarce capital for industrial, urban, and regional development, has given rise to expectations such as: Which are the most economical and effective sizes of urban centers for investment in infrastructure required for industrial development? Can the location of infrastructure facilities for which the governments in developing countries assume responsibility help in guiding industrial and urban growth for balanced economic development? Are there distinct industrial types and activities which are locationally suitable for different city sizes, so that programs to promote them in such areas can be formulated? These are direct policy implications and are related to decision making by the concerned public agencies. Then there is the expectation, by developmental executives and agencies, that new data will be generated by the research--i.e., data on important aspects of cost functions of specific urban facilities, infrastructure characteristics, and use intensities of different types of growth industries. A third type of expectation has been that the academic and research field will develop methodology for future location of industrial activities at minimum costs.

We have searched these questions in detail, within specified limits. The depth of investigation lies in close examination of the tangible, measurable, and quantifiable costs of industry infrastructure facilities, while the primary lack is that only indirect attention has been given to the intangible, unmeasurable, or nonquantifiable costs. Thus, the result is a partial analysis, and implications arising out of this should be recognized.

We first examine the implications of our findings for the India field region, and then consider their wider applicability.

Implications of the Research for the Study Region

One of the major conclusions of this report is that the unit costs of urban infrastructure for a projected industrial expansion of over 180 percent in a ten-year span are not significantly different for city sizes beyond 130,000. This is significant for evolving policies pertaining to the planning of infrastructure and industry locations. It clearly shows the "area of cost advantage" as related to the infrastructure for industrial development. A valid comment that might emanate from this conclusion is that the city size spectrum where the cost of industrial infrastructure does not differ widely is too large to guide choices of location. In other words, under conditions of similar costs, how are the public

agencies to make decisions on strengthening the infrastructure base for industrial growth from city sizes 130,000 to 1,070,000?

While the research data do not disclose cost differences in these city sizes, we view the problem in the following way. Since city sizes of over 130,000 offer about the same level of cost advantages, the alternatives open are: (1) obtain further cost and benefit data on agglomeration effects and intangible elements, a point that is of further research significance and is elaborated later; and (2) from trends in urban economic structure, seek guidance on locations that appear favorable to industrial development in the region. In the absence of (1), evidence from industrial statistics and field interviews suggests that steps to encourage industrial agglomeration may be effective in selected cities of around 130,000 to 300,000. As discussed on page 241, some cities in this size range or soon to enter this range have begun to generate manufacturing activities that promote diversified labor skills and other external economies favorable to industrial growth. This provides a positive answer, at least on present evidence, to the question posed in describing the analytical framework of the study in Chapter II: do cities of a size where low unit infrastructure costs are achieved also offer a basis for agglomeration economies? Since the composition of industry mix developed for the first cost test is oriented to cities of this size, it appears that the phase of low unit infrastructure costs for such industries coincides with the phase of incipient agglomeration advantages, at least in this region. Encouragement to industrial growth in favorably located cities of this size would take advantage of the phase of increasing benefits to agglomeration in places where these benefits are not yet countered by the possible social costs of the largest cities.

The second area of broad policy decision is related to selective promotion of industries in different city size groups on the basis of the locational and infrastructure appropriateness. It is axiomatic that all types of industries are not equally competitive, viable, and efficient in all city sizes, and the operation of certain types is rendered more effective under particular urban environments. The instance may be provided of two industries manufacturing (1) sophisticated electronic equipment, and (2) paper and straw board. These have different requirement characteristics. The manufacture of sophisticated electronic equipment will typically be more efficient in large cities which have developed external economies and specialized services. The manufacture of paper and straw board, because of the requirements of floor area, water use, and effluent disposal, would find important advantages in smaller cities, provided a sufficient volume of industrial activity had developed to reduce the unit costs of their principal infrastructure requirements, as shown in Chapter VI. This tenet of appropriateness has been pursued in the research with the main implication that the influence of city size in stimulating industrial growth should be recognized by the decision-making agencies while plans are being implemented. No doubt, the identification of industries for specific areas or cities must take into account many additional factors. The lists of industries provided in Table 79 serve as a starting point for further work in this area of practical use.

Pursuant to the above policy orientation, program measures appropriate for medium, metropolitan, and small cities in the field region may be briefly indicated.

A starting point with respect to cities in the 130,000 to 300,000 population range is established by the steps taken in Chapter V to formulate a relatively diversified industry mix suited to cities of this size. Prospective new industries were selected from among those types relatively common to cities of all sizes in the region (List A of Table 79) plus those oriented to medium cities (List C of Table 79). However, the resulting mix is not specific to any one city. A logical next step for industrial development agencies in the region, in consultation with prospective industrial investors, would be to identify those specific cities in or near this size range that offer a promising base for such industrial diversification In the selected cities, the relevant industrial promotion agencies would be assisted in analyzing specific advantages of location, resources, skills, market outlets, and existing industry linkages as a basis for identifying promising new manufacturing opportunities. In particular, List C industries in Table 79 would be assessed for investment feasibility in the chosen cities. Next, detailed examination of the requirements of these industries, with the aid of Tables 70 and 71, would indicate infrastructure bottlenecks to be met in the cities concerned. Following this, measures would be taken to provide the indicated incremental infrastructure or to meet other needs such as specialized training, financial support to specialized subcontracting enterprises, or regional market research. In short, a substantial, coordinated industrial promotion effort in selected cities of this size range appears to be timely in accelerating the realization of external economies and improved productivity.

With respect to the metropolitan (1 million) city included in the study, the following observations may be made. In order to test the implications, regarding the city's overall growth, of an incremental industrial mix of the size studied in Chapter V, projections were made of work force and population growth on the assumption that the manufacturing share of the work force will remain more or less constant. It was concluded that in order to absorb an industrial increment of the size considered, the metropolitan city would have to experience a general citywide growth at a faster rate than the high 1951 to 1967 rate. Given the severe pressure of the existing central city population on land and facilities, the city's capacity for an even more rapid expansion than in the past is open to serious doubt. The case for highly selective location of new industries is therefore particularly strong, focussing less on net expansion of industry than on facilitating the transfer of workers, plant, and infrastructure services from the city's slack textile industry into more productive lines. Orientation to the city's new scientific and technological resources is a logical growth path for future manufactures. The city performs central distribution and transport functions which can be expected to expand with future development of the region. As suggested by Desai

and Pal,* the relative importance of the city's regional service functions may grow and its relative share of manufacturing may not be maintained. This appears to the research team to be consonant with the functions of this metropolis.

With respect to smaller cities, particularly those expected to serve the process of agricultural modernization now under way in the study region, further research is needed on requirements and costs of industrial infrastructure. The criteria established for selection of five cities for developmental cost estimation, as described in Chapter V, did not permit adequate coverage in depth of cities of 20,000 to 50,000 and 50,000 to 100,000 in the region. As indicated in Lists A and B of Table 79, industries with promise for cities of this size are on the whole more narrowly oriented to local markets or resources than industries in medium cities. We have seen that industries of the types constituting the small city mix for the second test of the cost hypothesis are heavier users of direct industrial infrastructure per Rs. 1,000 value added than industries in the medium or large city mixes. In order to overcome the degree of infrastructure cost disadvantage indicated by the first test, this suggests that small cities must have favorable local cost factors or must be capable of attracting a volume of industry that permits scale economies in critical infrastructure inputs.

Information presented in Table 80 on the level of development and present use of facilities in cities of 20,000 to 50,000 and 50,000 to 100,000 among those covered in the research should facilitate local estimation of incremental infrastructure requirements and costs for prospective new industries in these cities. More broadly, further locational research is proposed toward selective identification of smaller cities which have promise as growth centers. Cities of these size categories in Clusters 1 and 2 of Table 4, which are defined by variables that indicate manufacturing potential, form a preliminary list for assessment as growth centers. To these would be added, particularly in the central and eastern parts of the region, cities located at transport and market nodes as well as those forming a transitional or break-in-bulk contact with other economic regions.

Research of the kind proposed should attempt to identify the principal economic functions of each city in an overall regional context. This is particularly required in the light of emerging industrial trends in some cities of 20,000 to 50,000 observed in the more industrially developed northwest part of the region. Such centers, well connected by road and telephone services, are developing industries in linkage with the specialized and more technologically advanced industries of medium and metropolitan cities. Thus, even among smaller cities, differentiation and specialization among manufactures can increasingly be expected to become the basis for future growth.

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* P. B. Desai and M. N. Pal, "Economic Activity in the Kanpur Region, Present Pattern and Perspective Dimensions," background paper for the International Seminar on Urban and Industrial Growth of Kanpur Region, Indian Institute of Technology, Kanpur, 1967. See reference 132.

Wider Relevance of the Results for Regional Development

Significance of Urban Infrastructure Cost Differentials

The significance of the cost conclusions of this study can be judged by comparing the annual costs of incremental urban infrastructure with the annual increase in net manufacturing output associated with these costs. As summarized in Table 104, the annual cost of incremental infrastructure amounts to 14.5 percent of the related value added in the city of 48,000 population, 13.3 percent in the city of 132,000, and 12.8 percent in the city of 1,070,000. These are significant amounts. To the best of our knowledge, these cost figures provide the first available indication of the magnitude of public urban costs required for a given level of net industrial output. We know of no comparable data that could be used as a benchmark for testing the return to investment or ranking of investment priorities implied by cost requirements of this order.

A somewhat sharper perspective is provided when cost differentials are compared. It is at once seen from the above figures that the cost differential between the smallest and largest city tested amounts to 1.7 percent of the related value added, and that within this differential, the decline from the 48,000 city to the 132,000 city accounts for 1.2 percentage points. Since we are dealing with by far the largest part of a city's equipment and services that directly meet the needs of industry and its employees, these cost differentials among cities of different size are modest.

We see three significant facts in the above relationships:

1. Infrastructure cost differences associated with city size are not of an order that would outweigh the influence of local factors unique to each city in determining infrastructure cost levels. This is to say that some cities larger and some smaller than 130,000 population, to use the field test example, may have higher or lower costs because of local circumstances. The question of particular cost advantages for a given city must be individually examined, with other factors as well as size taken into account.

2. It is difficult in our cost data to see a distinct minimum base or threshold size city with respect to costs. Economies of scale in specific facilities and their maintenance and operation costs largely explain the 8 percent decline in unit costs between the 48,000 and 132,000 cities, but the effect of scale economies in the overall cost package is attenuated strongly by the weight of those infrastructure elements in which scale is an insignificant cost factor. In particular, since lineal type costs amount to approximately 24 percent of total infrastructure, being relatively unaffected by scale economies, and since site development, housing, and schools add 47 to 55 percent more, these elements significantly reduce the combined influence of scale economies introduced by other elements. Further research on urban subsystems to

test these relationships is obviously needed. From the present data, the combined effect of elements influenced and not influenced by scale would appear to be one of a relatively gradual decline in unit infrastructure costs in the size range 50,000 to 130,000, not a sudden fall within a narrower size range. Individual elements marked by discontinuities or indivisibilities take on more modest perspective in the context of the overall spatial organization and costs of urban systems of infrastructure.

3. Local cost factors and the absence of a sharp threshold for urban infrastructure costs suggest that it should be possible to equip selected smaller cities for appropriate new industries without undue cost handicaps. This is particularly true for centers well served by intercity roads and other regional networks. Seen in the context of the spatial functions of urban centers described in Chapter II, the potential industrial role of selected smaller cities should not be disregarded because of the degree of cost difference demonstrated in the overall test of the cost hypothesis.

These findings confirm the importance of a regional basis for industrial development efforts. The role and interrelationships of cities of different sizes should be taken fully into account in planning the location of industry, as opposed to the claims of any particular city size class on grounds of infrastructure cost advantage alone.

Regional Approach to Urban Industrial Development

The readiness of an urban center to serve as a base for rapid industrial expansion is dependent on many more factors than its ability to achieve low unit costs of infrastructure. This was pointed out in setting the analytical framework for the present study in Chapter II. In addition to favorable infrastructure costs (lack of which may indeed be overcome by exceptional industrial stimuli or other advantages), attainment of a minimum economic base for profitable industrial growth requires many or all of the agglomerative advantages identified by Spiegelman as summarized in Chapter II. Further research is required on factors which contribute to the agglomeration process, particularly in medium size cities.

The evidence of interindustry links between medium and smaller cities in the western part of the study region, as well as within selected medium cities, provides empirical confirmation of the importance of regional networks which substitute proximity in time for proximity in space. Key elements of agglomeration are thereby achieved without requiring actual physical agglomeration. Modern communications enable firms in smaller cities to share the market and investment information current in larger cities more or less simultaneously. The importance of this factor is seen in the fact that 42 percent of the interviewed manufacturers cited delays in obtaining telephone service, from six months to two years, as principal handicaps among the infrastructure facilities in their cities. The significance of growing intercity linkages in the field region supports

Friedmann's emphasis on "regional development corridors" and strengthens the case for "selective concentration" (see pages 23-24). To take advantage of the specialized resources and initiatives of particular small cities, attention to gaps or bottlenecks in regional infrastructure should precede or coincide with development of urban industrial infrastructure.

The regional standpoint contributes to an analysis of the advantages, for prospective industries, of cities having different economic strengths. Complementarity among industries in cities of different size can be fostered. If taken as suggestive, not predictive, the city size characteristics of industries presented in Appendix B should be instructive in such analyses. The status of regional transport networks is an important factor in such evaluations. Once roads are well developed, local investment proposals for industries thought to be ubiquitous should be scrutinized closely, to be certain that they respond genuinely to local needs and advantages rather than simply sheltering behind earlier high transport costs.

The contribution of multiple stimuli or multiple causation to creation of a well-distributed size structure of cities, noted in Chapter II, can be fostered in a regional context. Technological education, not examined in this study of urban facilities, adds an important dimension to regional modernization. An engineering college, polytechnic, or other specialized institute invariably serves a wider population than that of the city where it is located. Methods of maximizing educational linkages with emerging industries call for research including study of catalytic locational patterns. Addition of a technological institute to a small city that is already emerging as a transport and market node could provide a significant margin of advantage to related new industries.

Infrastructure Development Sequences and Investment Decisions

The inventory of city infrastructure reported in Chapter V, and the detailed cost estimates on urban infrastructure for incremental industry offer instructive evidence on stages of infrastructure development. They suggest that costs of urban infrastructure for industry as related to city size will have different connotations in developing countries and developed countries.

The low proportion of off-site costs in total annual costs, 7 to 9 percent as summarized in Table 101, shows their minimal influence in the total package of incremental infrastructure costs. This is an indication of low levels of development of city systems in individual facilities with which the incremental industry could integrate. This may be viewed in the perspective of overall development in a developing country. Where city systems are not fully developed, infrastructure linkages to existing facilities are reduced as a factor influencing the level of costs in cities of different size. In such instances, the unit costs of infrastructure expansion are heavily oriented to first costs and are therefore dependent primarily on the scale or magnitude of the industrial development.

In contrast, where city systems are fully developed for most facilities, the costs of infrastructure expansion will more typically be oriented to linkages with existing systems. Costs in such cases would be governed more by incremental facility requirements and by the attained level of annual maintenance and operation costs, as opposed to first costs.

In the process of urban expansion, even in the cities tested for incremental costs, the successive in-filling of appropriate areas has a larger role than might be inferred from the procedure of concentrated development used in this study for purposes of cost comparison. Economies through in-filling have no necessary relation to city size, but close attention to such local opportunities in the context of the city's overall development plan can assure cost savings.

Looking ahead to future development of city systems in many facilities, the influence of urban infrastructure linkages may increase as a major cost factor in choice of industry location among different size cities. This is dependent, however, on such policy issues as the development of urban facility systems, the choice and priority among facilities, and their integration in the context of urban planning and development.

The special characteristics of urban water supply in the study region reduce the influence of nodal and lineal facility costs, in view of the underground source which requires minimal treatment and can be tapped in virtually any locale of the city. This is a specific feature of the study which is clearly not transferable to regions having other sources of city water supply. However, costs of component elements reported in Chapter III are relevant for analyses elsewhere. Water systems based on river or reservoir sources require cost analysis that includes assessment of scale economies in treatment plants and the increased distribution costs required for more extensive lineal connectors throughout the city.

The relatively incomplete stage of development of many urban facilities in developing countries underscores the importance of applying engineering-economy techniques in investment planning for capacity expansion. The cost functions developed in Chapter III are expected to be of direct use in identifying the major parameters of cost and the magnitude of scale economies for specific facilities. The actual costs reported, of course, must be adjusted for local design factors and price relationships. The sample of reported costs for many of the facilities studied in Chapter III is neither large enough nor sufficiently representative of contrasting construction conditions to serve as a definitive basis for estimation of cost functions in other locales. The chapter does provide the initial elements of a useful cost handbook, hopefully encouraging further comparative research efforts on effects of scale and other major variables on urban facility costs. Special attention to maintenance and operation costs is required, especially in view of the difficulties of obtaining comparable accounting data for these recurring costs in varying urban circumstances.

Evidence on facility costs related to capacity is of particular importance in determining design capacity for a given period and projected load. Installation of extra capacity for basic industrial requirements such as power, water, and transport is frequently adopted as a technique for attracting new industrial investment. The potential return to such infrastructure development must be critically assessed, especially in countries with scarce capital resources. Examination of annual capital costs for alternative interest rates, such as those employed in this study, is a necessary tool in such investment evaluation.

It can be stated with confidence that sound planning, phasing, budgeting, and management of urban infrastructure facilities and services have as much influence as city size in determining real costs, or may have greater influence. The complexity of such facility management increases disproportionately with city size. Expanded collaboration of city planners, economists, engineers, and administrators in the evaluation and management of infrastructure costs is accordingly of great significance in the establishment of effective urban infrastructure for industrial progress in developing countries.

Appendix A

DERIVATION OF FACILITY COSTS

Appendix A

COST QUESTIONNAIRE - CITY STREETS AND ROADS

Costs of Urban Infrastructure for Industrial Development
(A Joint Study: SPA-SRI-SIET. Approved by Govt. of India)

Code No._____ Source_____

Location (City and State)_____ Initials_____

Name of the project_____

Total cost of project (Rs.)_____ Length of Street (miles/feet)_____

Year project constructed_____ Land Cost (Rs.)_____

Metalled width (feet)_____ R.O.W. (feet)_____

Formation width (feet)_____ Width of pedestrian paths (feet)_____

DESCRIPTION OF PROJECT

Provide description of base course and wearing course and show by sketch giving road section dimensions, etc.

CONSTRUCTION COSTS

Item	Estimated Cost and Year (Rs.)	Actual Cost and Year (Rs.)
1. Embankment		
2. Road Section		
3.		
4.		
5.		
6.		
Total		

COSTS FOR ANNUAL REPAIRS AND RE-SURFACING

Year	19	19	19
Establishment (Rs.)			
Structures (Rs.)			
Miscellaneous (Rs.)			

Specify whether cost is actual or tendered or estimated - Use A for actual, T for tendered, and E for estimate.

Table A-1

PRICES OF BUILDING MATERIALS AND WAGES OF CONSTRUCTION LABOR in 18 Cities, 1962-67 (Rupees)

State and City	Bricks* (per thousand)						Cement (per cwt)						Sand+ (per 100 cu ft)					
	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967
Punjab																		
Jullundur	43 08	43.30	43.52	44 00	44.33	53.00	7.39	7.54	7.68	8.59	10.14	10.50	33.83	36.42	39.00	39.00	43.15	47 30
Phagwara	39.10	41.20	43.30	43 79	46.08	51.05	7.57	7 74	7.93	8.87	9 99	10.00	29 45	32.54	34.00	36.89	38.40	42.89
Ludhiana	43.56	43.78	44.00	45.00	47.34	52.45	7.39	7.71	8.02	8.56	10.11	10 12	28.67	35.91	43.14	48.00	49.97	55.82
Patiala	42.68	42 89	43.10	43.17	44.23	49.10	6.83	6.98	7.15	8.00	9.00	10.22	30.31	33 49	35.00	35.00	35.00	39.10
Average (4 cities)	42.11	42.79	43.48	43.99	45.50	51 40	7.30	7.49	7.70	8.51	9.81	10.21	30.57	34.59	37.79	39.72	41 63	46.28
Haryana																		
Ambala	39.10	41.20	43.30	43.79	46.08	51.05	7.39	7.55	7.74	8.66	10.23	10.24	32.50	35.90	37.51	40.71	42.36	47.30
Jagadhri-Yamunanagar	31.01	33.03	34.05	34.77	38.49	38.87	7.20	7.43	7.70	8.42	9.59	10.10	24.47	26.84	29.23	31 63	34.54	40.00
Karnal	34.00	36.77	38.50	40.75	43.00	46.00	7 27	7.37	7.47	8.50	9.79	10.20	29.67	32 55	33.89	36.67	37.67	39.33
Bhiwani	36.85	39.25	40.47	41.32	45.74	46.20	7.69	7.94	8.23	9.00	10.07	10.50	39.76	43 62	47.50	51.40	56.13	65.00
Average (4 cities)	35.24	37.56	39.08	40.16	43.33	45.53	7.39	7.57	7.79	8.65	9.92	10.26	31.60	34.73	37.03	40.10	42.68	47.91
Uttar Pradesh																		
Saharanpur	40.45	40.69	44.73	45.09	45.45	50.00	6.99	7.08	7.32	8.10	8.10	9.00	35.05	39.08	42.17	45.00	45.00	49.50
Modinagar	44.50	45.00	49.22	49.61	50.00	55.00	7.19	7.28	7.53	8.34	8.94	9.65	35.43	39.50	42.62	45.48	47.44	48.67
Hapur	44.50	45 00	49.22	49.61	50.00	55.00	7.61	7.95	8.22	9.10	9.75	10.53	29.60	33.00	35 61	38.00	39 64	40.67
Amroha	44.50	44.62	44.73	45.09	45.45	50.00	7.50	7.76	8.19	9.07	9.72	10.50	27.33	30.47	39.41	42.05	43.86	45 00
Bareilly	44.50	45.00	49.22	49.61	50 00	55.00	6.92	7.01	7.25	8.03	9.07	9.81	33.25	37.07	40.00	41.00	42.00	43.33
Kanpur	39.60	40.00	40.00	40.62	41.24	53.65	7.51	7.61	7.87	8.71	9.03	9.75	31.53	35 16	37.94	40.48	42.22	43.32
Faizabad	32.01	33.45	34.89	38.00	42.00	44.00	6.48	6.56	6.78	7 50	8.50	10.75	36.36	40.54	43.74	46 67	46.67	46 67
Gorakhpur	39.00	40.75	42.50	45.00	50.00	55.00	7.27	7.36	7.61	8 50	8.50	9.00	34.91	38 92	42.00	53.33	56 33	64.00
Maunath Bhanjan	42.12	44.02	45.91	50.00	50 00	55.00	8.08	8.18	8.46	9.37	10.00	11.30	43.87	48.92	52.79	56.33	56.33	64.00
Varanasi	38.00	39.71	41.32	45.00	48.00	48.00	7.86	7 96	8.23	9.11	9.60	10 17	36.67	38.02	39.36	42 00	43 33	44.67
Average (10 cities)	40.92	41.84	44.17	45.76	47.21	52.07	7.27	7.48	7.75	8.58	9.12	10.05	34 40	38.09	41.56	45.03	46.28	48.98
Average (18 cities)	39.92	41.10	42.89	44.12	45.97	50.47	7.35	7 50	7.74	8.58	9.45	10.13	32.93	36.55	39.72	42.76	44.45	48 14

* Average rate of 50 percent first class and 50 percent second class bricks

\+ Average of $\frac{2}{3}$ coarse and $\frac{1}{3}$ fine sand.

Table A-1 (continued)

State and City	Aggregate‡ (per 100 cu ft)						Steel§ (per cwt)						Timber** (per cu ft)					
	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967
Punjab																		
Jullundur	61.50	63.44	65.37	65.57	65.77	65.97	38.48	38.60	38.72	41.53	43.23	45.00	19.18	17.64	16.10	15.52	20.69	22.84
Phagwara	63.69	71.97	85.00	87.32	89.73	90.00	38.77	38.96	39.00	41.30	43.23	45.00	14.80	14.93	15.06	15.56	17.53	18.00
Ludhiana	60.00	65.20	70 40	70 61	70.82	71.03	38.48	39 28	40 07	40.75	42.42	44.16	13.70	14.90	16.10	15.75	19.14	19.66
Patiala	52.45	59.27	70.00	70.21	70.42	70.63	36 06	36.24	36.28	38.42	40.00	43.35	13.46	13.56	13.70	15.95	16.81	18.10
Average (4 cities)	59.41	64.97	72.69	73.43	74.19	74.41	37.95	38.27	38.52	40.50	42.22	44.38	15.29	15.26	15.24	15.70	18.54	19.65
Haryana																		
Ambala	59.67	67.45	76.67	79.89	80 11	80.32	38.48	38.69	38.73	41 00	42.69	44.45	14.98	15 11	15.24	15.74	19 12	19.64
Jagadhri-Yamunanagar	59.67	67.45	76.67	79.89	80.11	80.32	39.65	39.85	39.89	43.16	44.45	47.03	14.98	15.11	15.24	15.74	19.12	19.64
Karnal	63.00	71 19	84.07	84.32	84.57	84.82	38.32	38 51	38.55	40.66	42.76	45.24	14.98	15.11	15.24	15.74	19.12	19.64
Bhiwani	59.67	67.45	76.67	79.89	80.11	80.32	39.65	39.85	39.89	43.16	44.45	47.03	14.98	15.11	15 24	15.74	19.12	19.64
Average (4 cities)	60.50	68.39	78.52	81.00	81.23	81.45	39.03	39.23	39.27	42.00	43 59	45.94	14.98	15.11	15.24	15.74	19.12	19.64
Uttar Pradesh																		
Saharanpur	42.68	47.46	53.82	55.00	60.00	65.00	41.99	42.28	42.4[illegible]	45.00	45.00	45.00	12.00	12.04	12.08	12.45	13.00	14.50
Modinagar	56.12	62.41	70.77	72.33	80.65	90.00	40.79	41.08	41.24	43.71	45.85	47.87	11.71	11.75	11.79	12.16	12.70	15 00
Hapur	49.69	55.48	62.91	64 29	71.68	80.00	39.38	39.66	39 82	42 21	44.28	46.23	23.46	23.53	23.60	24.33	25.40	30.00
Amroha	49.89	55.48	62.91	64.29	71.68	80 00	39.19	39.46	39.62	42.00	44.06	46.00	15.63	15 68	15.73	16.22	16.93	20.00
Bareilly	62.63	69.65	78 98	80.72	90.00	100 44	40.91	41.20	41.36	43.84	45.99	48.01	15.65	15.70	15.75	16.24	16.53	19.52
Kanpur	107.91	120.00	123.50	127.00	137 00	147.00	37.88	38.15	38 30	40 60	40.60	42.39	11.58	11.61	11.64	12.00	13.00	15.35
Faizabad	108 63	120.80	136.99	140 00	145.00	150.00	40.48	40.76	40 92	43.37	45.50	47.50	11.92	11.96	12.00	12.37	12.91	15.25
Gorakhpur	109 29	121.53	137.81	138.91	140 00	160.00	41.54	41.63	42.00	44.52	45.98	48.00	11.58	11.61	11.64	12.00	13.50	14.00
Maunath Bhanjan	118.72	132.02	149.71	153.00	153.00	197.50	42.70	43 00	43.17	45.76	48.00	48.00	11.58	11.61	11.64	12.00	13.00	16.00
Varanasi	98.94	110.02	124.76	127.50	140.00	170.00	32.66	32.89	33.02	35.00	37.00	38.63	16.44	16.49	17.46	18 00	20 00	20.00
Average (10 cities)	80.47	89.49	100 22	102.30	108.90	123.94	39.75	40.03	40.19	42 60	44.23	45.76	14.16	14 20	14 33	14 78	15 70	17.96
Average (16 cities)	71.35	79.35	89.28	91.15	95.04	103.49	39.19	39.46	39.61	42.00	43.64	45 49	14.59	14.64	14.74	15.20	17.09	18.71

‡ Average of 50 percent ¾" and 50 percent 1½" gauge stone ballast
§ Mild steel round bars, average size
** Sal (shorea robusta).

Table A-1 (concluded)

State and City	Mason†† (per day)						Carpenter†† (per day)						Unskilled Labor (per day)					
	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967	1962	1963	1964	1965	1966	1967
Punjab																		
Jullundur	6.00	6.25	6.50	6.00	6.00	7.50	6.00	6.25	6.50	6.00	6.00	7.50	2.40	2.45	2.50	2.50	3.00	3.50
Phagwara	5.87	5.94	6.00	7.11	8.22	10.00	5.87	5.94	6.00	6.05	6.59	7.32	2.40	2.45	2.50	3.37	4.24	5.00
Ludhiana	6.00	6.19	6.37	7.00	7.67	9.33	6.00	6.19	6.37	7.00	7.63	8.48	2.51	2.57	2.62	3.00	3.62	4.26
Patiala	5.70	5.77	5.83	6.00	7.50	7.75	4.94	5.00	5.05	5.50	6.50	7.50	2.40	2.45	2.50	2.50	3.00	3.00
Average (4 cities)	5.[illegible]9	6.04	6.18	6.53	7.35	8.65	5.70	5.85	5.98	6.14	6.68	7.70	2.43	2.48	2.53	2.84	3.47	3.94
Haryana																		
Ambala	6.00	6.07	6.13	6.31	6.92	8.42	6.00	6.07	6.13	6.19	6.75	7.50	2.30	2.35	2.39	2.69	3.25	3.83
Jagadhri-Yamunanagar	5.77	5.94	6.47	6.86	7.67	9.00	7.32	7.32	7.50	7.67	7.83	9.00	2.14	2.14	2.25	2.37	2.43	2.75
Karnal	5.75	5.75	5.75	6.50	7.00	9.00	6.25	6.25	6.40	6.87	7.00	9.00	2.25	2.25	2.25	2.50	2.50	3.50
Bhiwani	5.25	5.41	5.91	6.26	7.00	8.00	5.62	5.62	5.75	5.88	6.00	6.00	1.76	1.76	1.85	1.95	2.00	2.50
Average (4 cities)	5.69	5.79	6.07	6.48	7.15	8.61	6.30	6.32	6.45	6.65	6.70	7.88	2.11	2.13	2.19	2.38	2.55	3.15
Uttar Pradesh																		
Saharanpur	4.09	4.33	4.33	5.00	5.50	6.00	3.88	3.95	4.13	5.00	5.50	6.00	1.15	1.35	1.36	1.58	1.61	1.70
Modinagar	4.09	4.33	4.33	5.00	5.77	6.35	4.04	4.12	4.31	5.22	6.06	6.25	1.51	1.78	1.80	2.09	2.13	2.70
Hapur	4.74	5.02	5.02	5.80	6.69	7.25	4.67	4.76	4.99	6.05	7.03	7.25	1.97	2.32	2.34	2.71	2.76	3.50
Amroha	3.25	4.00	4.00	4.50	5.50	6.50	3.00	3.50	3.75	4.55	5.57	5.75	1.50	1.75	1.88	2.00	2.25	2.50
Bareilly	4.25	4.50	4.50	4.50	4.50	4.50	4.23	4.31	4.50	5.45	6.33	6.53	1.89	2.23	2.25	2.61	2.66	3.37
Kanpur	4.50	5.00	5.50	5.75	6.00	7.00	4.87	5.00	5.50	6.00	6.00	6.50	1.60	2.00	2.00	2.00	2.50	2.87
Faizabad	3.81	4.10	4.18	4.66	4.87	5.30	3.98	4.11	4.30	5.00	5.50	6.00	1.10	1.30	1.33	1.50	2.00	2.50
Gorakhpur	3.68	3.96	4.04	4.50	4.50	5.00	4.20	4.33	4.52	5.25	6.25	7.75	1.64	1.95	1.99	2.25	2.75	3.00
Maunath Bhanjan	4.10	4.41	4.49	5.00	5.50	6.50	3.98	4.11	4.30	5.00	5.00	6.00	1.46	1.73	1.77	2.00	2.25	2.50
Varanasi	3.53	3.80	3.87	4.31	4.50	5.00	4.11	4.24	4.43	5.15	5.44	6.12	1.00	1.19	1.21	1.36	1.50	1.75
Average (10 cities)	4.00	4.35	4.43	4.90	5.33	5.93	4.10	4.24	4.47	5.27	5.87	6.42	1.48	1.76	1.79	2.01	2.24	2.64
Average (18 cities)	4.80	5.04	5.18	5.61	6.18	7.13	4.94	5.06	5.25	5.77	6.28	7.03	1.74	2.00	2.04	2.28	2.58	3.04

†† Average of first and second grade

Sources: Field surveys; Central Public Works Department, New Delhi; Post and Telegraph Department, New Delhi. Where figures for a given place and year were unavailable, they were interpolated.

Appendix B

ANALYSIS OF INDUSTRIAL LOCATION AND INFRASTRUCTURE REQUIREMENTS

Appendix B

INDUSTRY QUESTIONNAIRE

SMALL INDUSTRY EXTENSION TRAINING INSTITUTE, HYDERABAD
SCHOOL OF PLANNING AND ARCHITECTURE, NEW DELHI
STANFORD RESEARCH INSTITUTE, CALIFORNIA

City _____ Serial No. _____

Industry Code _____

Costs of Urban Facilities for Industrial Development
Questionnaire for Selected Industrial Firms

Person interviewed_____Position in firm_____

1. IDENTIFICATION

   1.1 Name of Firm _____

   1.2 Address_____

   1.3 Year established_____

2. LOCATION, SITE, AND PLANT

   2.1 Reasons for locating the plant in this city:

   _____

   2.2 Present location in the city: Central business area ____; Industrial area____; Corporate area____; Industrial estate____; Urbanisable area____.

   2.3 Total site area_____sq yds 2.5 Total floor space_____sq ft

   2.4 Built up area_____sq yds 2.6 Present land price per sq yd: Rs._____

   2.7 Ownership: Owned____ Rented____ Rent Rs._____ per month

   2.8 Investment in machinery and equipment: Initial Rs._____ 1966 Rs._____

3. PRODUCTION AND CAPACITY

   3.1

Major Products	Weight per unit shipped	Production 1961-62 Quantity	Production 1961-62 Rs.	Production 1966-67 Quantity	Production 1966-67 Rs.	Year of Maximum Production (specify) Quantity	Year of Maximum Production (specify) Rs.

3.2 Period of production (1966-67)

If seasonal, specify months in operation_____

Number of days worked_____Work hours per day_____

3.3 Maximum annual installed capacity with existing machinery and employment Qty._____ Rs._____.

3.3.1 Do you have unutilised capacity? Yes_____ No _____
If yes, can it be made good with increased employment? Yes___ No___

3.3.2 How many additional hands would you require to fully utilise the above capacity?_____

3.4 Production Constraints:

Market_____Raw materials_____

Services (specify)_____Labour_____

Machinery_____Management_____

Working capital_____

4. ELECTRIC POWER

4.1 Total horsepower of installed electric motors_____HP

4.2 Public power supply: Sanctioned load_____kw

4.3 Connected load_____kw

4.4 Units of power purchased (1966-67) (kwh), monthly,

_____ _____ _____ _____

_____ _____ _____ _____

_____ _____ _____ _____

4.5 Total cost of power purchased (1966-67)_____Rs.

4.6 Average hours lost per month through power failures/shutdowns___

4.7 Actual losses on account of power failures and voltage fluctuations (1966-67):

(a) Production loss Rs._____

(b) Out of pocket expenses Rs._____

4.8 Does the supply of power meet your requirements? Yes____ No____

If no, what is your required additional connected load?_____kw

4.9 Has your production been affected by peak hour restrictions? Yes___ No___

4.10 If yes, are you prepared to accept night load? Yes____ No____

4.11 Difficulties in using night loads_____

4.12 If you maintain a generator for stand-by or regular use, please give details_____

4.13 Have you shifted your production from peak hours to non peak hours?

(a) If yes, to what extent_____

(b) If no, state reasons_____

5. WATER

5.1 Source:

Municipal supply____ Private tubewells____ Hand pumps____

5.2 If private tubewell:

Depth_____ft. Capacity of tank_____gallons

Rated capacity_____gallons per day.

Cost of well_____Rs. Year of construction_____.

5.3 Is water used in production? Yes____ No____

5.4 Quantity requirements:

Maximum quantity required _____gallons per day.

Have you faced fall in production on account of:

Restricted water supply?_____

Seasonal shortages?_____

6. SEWAGE AND INDUSTRIAL WASTE DISPOSAL

6.1 Sanitation purposes:

Flush type facilities Yes____ No____ Number_____

6.2 If your firm has flush system, state method of discharge

Septic tank_____ Municipal main_____

6.3 Industrial waste requiring treatment:

Type	Quantity	Method of Disposal	Treatment Required

7. TRANSPORTATION

7.1 Raw materials

Item	Bought Locally: Locally Processed or Produced (kg)	Bought Locally: Coming From Outside (kg)	Procured Directly From Outside Source (kg)	Mode of Transport for Raw Material Purchased from Outside: Rail (kg)	Mode of Transport for Raw Material Purchased from Outside: Road (kg)
1.					
2.					
3.					
4.					
Others					

7.2 Finished Products

Item	Sold Locally: Estimated Local Use (kg)	Sold Locally: Outside Use (kg)	Directly Sold Outside (kg)	Mode of Transport for Sold Outside: Rail (kg)	Mode of Transport for Sold Outside: Road (kg)
1.					
2.					
3.					
4.					
Others					

7.3 Is improvement needed in road transport routes or vehicles?

Yes____ No____ Specify_____

7.4 Are new or special types of freight handling facilities required at rail terminals? Yes____ No____ Specify_____

_____

8. WAREHOUSE/STORAGE

8.1 Within the factory: Covered_____sq ft Uncovered_____sq ft

Outside the factory: Covered_____sq ft Uncovered_____sq ft

Specify facilities (specify, e.g. cold storage)_____

8.2 If your present storage facilities are not adequate, what additional area is required? _____sq ft

9. COMMUNICATION AND INFORMATION

9.1 State your average monthly charges for the following services:

Local telephone Rs._____ Long distance telephone Rs._____

Postage and telegrams Rs._____

9.2 Any special/persistent difficulty regarding: Postal/telegraphic services: Yes____ No____

9.3 Average number of trunk calls per month to: Delhi_____ Bombay_____

Calcutta_____Chandigarh_____Lucknow_____Kanpur_____

9.4 What is the average time (minutes) required to place an ordinary call to

Delhi_____Bombay_____Calcutta_____Chandigarh_____Lucknow_____

Kanpur_____

9.5 Time lag for getting telephone connections_____.

10. PERSONNEL

10.1 Employment (1966-67)

Income Range (Rs./month)	Number of Employees Production	Office
Below 100	_____	_____
100 - 200	_____	_____
200 - 300	_____	_____
300 and above	_____	_____

10.2 Use and opinion regarding technical and management training facilities:

	Number of Trained Persons	Local or Outside Useful	Not Useful
1. Own plant (regular program)	_____	_____	_____
2. Industrial Training Institute	_____	_____	_____
3. Small Industries Service Institute Full-time	_____	_____	_____
4. Small Industries Service Institute Part-time	_____	_____	_____
5. National Productivity Council	_____	_____	_____
6. Production-cum-Training Center	_____	_____	_____

10.3 Industrial service and testing facilities

Services/facility used	In town	Out of town
_____	_____	_____
_____	_____	_____
_____	_____	_____

10.4 What are your requirements for additional skilled workers, specially qualified, or trained employees in the next three years?

Personnel	Present Number	Next 2-3 yrs. (additional)
Managerial	_____	_____
Engineering - Scientific	_____	_____
Supervisor - Foreman	_____	_____
Accountant - Office Manager	_____	_____
Marketing sales	_____	_____
Tool and die maker-precision machinist	_____	_____
Foundrymen	_____	_____
Electrician	_____	_____
Laboratory technicians	_____	_____
Shaping or milling machine or lathe operator; fitter, welder, other	_____	_____

11. HOUSING, HEALTH AND RECREATIONAL SERVICES

11.1 Housing

Does your firm provide housing for its employees? Yes____ No____

11.2 Health

Is the firm a beneficiary of the Employees Health Insurance Services?

Yes____ No____

If no, does the firm compensate employees for illness and accidents?

Yes____ No____ Specify the amount (1966-67)_____

11.3 Recreation

State the type of recreational facilities organised by the employees to which your firm contributes: Specify the amount (1966-67) Rs._____

_____

12. What improvement in your city's facilities or municipal services are needed to help increase production in your firm?

_____

_____

_____

13. FUTURE PLANS AND REQUIREMENTS

13.1 Do you have plans for expanding production/employment in the next 2-3 years with existing plant and machinery? Yes____ No____

13.2 If yes, anticipated additional employment_____ Year_____

Anticipated additional annual production level (over 1966-67)

Existing Products	Quantity	Rs.
_____	_____	_____
_____	_____	_____
New products (specify)		
_____	_____	_____

13.3 Land area required for expansion:

Total additional area_____sq yds

Additional floor space_____sq ft

Would you prefer to expand at the present site _____

Some other site in this town_____ Industrial estate_____

Industrial area of your town_____ Another town_____

Explain your reasons of preference_____

_____

13.4 What will be your additional power requirements after the expansion?

Connected load_____kw.

13.5 Water requirements as related to expansion:

Production purposes_____gallons per day.

13.6 Specify the quantity of industrial sewage likely to be discharged due to increased production:

Type	Quantity
_____	_____
_____	_____

Would these require any specific type of disposal facilities?

Specify_____

_____

13.7 State your requirements of additional "capital" to finance your expansion plans: Capital required Rs._____

Indicate roughly the sources from which you will raise this capital:

Own capital Rs._____ Partner's or shareholders' capital Rs._____

Loans: Long-term Rs._____Medium-term Rs._____Short-term Rs._____

14. INDUSTRY PERFORMANCE

Does your firm emit: smoke_____ odors_____ dust_____

vibration_____ noise_____

Interviewer_____

Date_____

PROCESS CHARACTERISTICS

Description of the Process	Types of Machines and Their Alternative Uses	Machinery and Equipment Cost (Rs.)	Capacities in Units (specify time period)	Daily Time Use for Each Process (hours)	Employees (number)				Floor Space (sq ft)	Con-nec-ted Load (kw)	Water Used (gals)
					Skilled	Semi-skilled	Un-skilled	Super-visory			

Table B-1

CRITERIA FOR CLASSIFICATION OF U.S. INDUSTRIES BY CITY SIZE*

Category	Description	City Population Class (1950)	Employment Criterion (1954)†	Equivalent Location Quotient
I.	Very high incidence in large cities	500,000 or more	50 percent or more	2.82 or move
II.	High incidence in large cities	500,000 or more	35 to 50 percent	2.00 to 2.81
III.	High incidence in medium cities and substantial in smaller cities	100,000-499,999 10,000-99,999	50 percent or more, of which at least $\frac{3}{5}$ were in cities of 100,000-499,999	1.69 or more
IV.	High incidence in smaller cities and substantial in medium cities	10,000-99,999 100,000-499,999	50 percent or more of which at least $\frac{3}{5}$ were in cities of 10,000-99,999	1.53 or more
V.	Wide incidence in all size cities	(a) Over 2,500 (b) Over 10,000	Category determined by location quotient	.75 or more‡ .75 or more‡
VI.	High incidence in small cities outside metropolitan areas	10,000-49,999	50 percent or more outside SMAs, 15 percent or more in cities of 10,000-49,999	Not available
VII.	High incidence in smallest cities	2,500-9,999	Category determined by location quotient	2.00 or more‡
VIII.	Wide incidence in non-urban as well as urban places	Less than 2,500	Category determined by location quotient	.75 or more‡
IX.	High incidence in non-urban places, (a) within, and (b) outside metropolitan areas	Less than 2,500	50 percent or more	1.21 or more

* See Appendix B, Table B-2, for individual industry location quotients.
† Percentage in the specified city size class or classes.
‡ Not meeting the criteria for other categories.

Table B-2

LOCATIONAL CATEGORIES OF MANUFACTURING INDUSTRY AS RELATED TO SIZE OF PLACE U.S., 1954

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
Percent of U.S. Population, 1950:			56.1	17.7	11.8	5.9	13.7	9.7	41.2
I. Very high incidence in large cities									
2013	Prepared meats	45.0	90.6	2.92	1.79	0.69	0.53	0.35	0.30
2045	Flour mixes	5.6	96.4	3.33	1.14	1.68	.89	.12*	.05*
2071	Confectionery products	66.8	90.3	2.88	1.67	1.47	.81	.37	.15
2082	Beer and ale	81.3	74.7	3.27	2.07	.83	.58	.29	.05
2095	Flavorings	10.6	92.1	2.99	1.81	1.05	.73	.30	.16
2253	Knit outerwear mills†	46.4	78.7	2.85	1.00	1.47	.72	1.10	.20
2311	Men's and boys' suits and coats	119.0	85.1	3.36	1.36	.39	.60	.97	.11
2323	Men's and boys' neckwear	9.5	95.9	4.21	.92	1.02	.40	.18	.03
2325	Men's and boys' cloth hats	8.1	82.4	3.39	1.36	.37	.42	n.a.	n.a.
2333	Dresses, unit price	143.3	91.9	3.63	.91	.81	.72	.63	.11
2337	Women's suits, coats and skirts	96.0	91.2	3.55	1.22	.83	.47	.64	.13
2338	Women's neckwear and scarves	1.7	(90-95)	4.56	.34	1.22	n.a.	n.a.	n.a.
2339	Women's outerwear, n.e.c.	25.4	85.4	3.06	1.09	.66	.76	.95	23
2351	Millinery	20.2	94.9	4.31	.52	.93	.16*	n.a.	.08*
2363	Children's coats†	14.4	91.1	2.99	.94	1.02	1.24	.80	.13
2371	Fur goods	10.0	97.8	5.39	.11	.05	.16	n.a.	n.a.
2384	Robes and dressing gowns†	11.0	77.4	2.98	.95	.66	.87	1.37	.16
2385	Waterproof outer garments	12.9	79.0	2.95	1.11	1.34	.64	.61	.30
2387	Belts	12.6	90.4	3.89	.87	.80	.41	.52	.13
2391	Curtains and draperies	14.0	92.2	3.02	2.15	.66	.72	.41	.08
2395	Tucking, pleating and stitching	6.5	98.0	4.90	.20	.34	.28*	.12*	.06
2396	Trimmings and art goods	17.8	86.8	3.57	.30	n.a.	1.55	.30*	.16
2397	Embroideries, except Schiffli	5.7	98.1	4.70	.28	.64	.42*	.23*	.03
2493	Mirror and picture frames	5.2	90.4	3.95	1.04	.20	.61	.04*	.09*
2519	Household furniture, n.e.c.	1.3	84.3	4.01	.53	n.a.	.77*	n.a.	.08*
2721	Periodicals	62.4	95.9	3.65	1.15	1.12	.87	.12	.05
2741	Miscellaneous publishing	18.4	94.1	3.34	1.42	1.17	.65	.54	.08
2761	Lithographing	77.7	92.4	3.01	1.77	1.12	.69	.41	.13
2771	Greeting cards	21.3	89.5	3.27	1.28	1.53	.64	.08	.21
2781	Bookbinding	17.2	96.3	4.20	1.25	.88	.27	n.a.	n.a.
2789	Miscellaneous bookbinding work	3.3	99.2	4.97	.71	n.a.	.12	n.a.	.03
2791	Typesetting	14.6	98.4	4.19	1.51	.63	.18	.03	.04
2792	Engraving and book plating	7.5	95.7	3.09	2.53	.69	.33	.19	.12
2793	Photo-engraving	17.7	95.4	3.70	1.76	1.03	.42	.09	.02
2794	Electrotyping and stereotyping	8.0	96.0	4.21	1.37	.39	n.a.	n.a.	.07*
2891	Printing ink	7.6	97.9	3.19	1.53	.44	.71	.76*	.12*
3171	Handbags and purses	22.9	88.1	3.46	.52	.64	1.25	.31	.21
3199	Leather goods, n.e.c.	4.6	92.4	3.76	.67	.69	.78	.26	.20
3298	Statuary and art goods	1.7	89.0	4.07	.93	.14	.45*	.22*	.14
3465	Enameling and lacquering	5.5	92.6	3.12	1.58	.46	.53*	.14*	.33
3467	Engraving on metal	3.5	90.5	3.18	.88	.78	.74*	.61	.08*
3555	Printing trades machinery	12.0	91.4	2.93	1.08	1.88	.71	.44	.25
3616	Electrical control apparatus	79.3	91.2	2.97	.61	1.73	.85	.90	.24
3942	Dolls	15.1	95.5	4.21	.79	.83	.44	.15	.09

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
3953	Hand stamps and stencils	5.7	92.1	3.16	2.08	61	.50	.49*	.04
3962	Artificial flowers	7.3	85.7	3.81	.88	.42	.55	.38	.21
3987	Lampshades	5.0	94.3	3.99	.71	1.20	.40*	.01*	n.a.
3994	Hairwork	1.7	99.5	4.62	.37	.20	.81*	n.a.	.02*
3995	Umbrellas, parasols and canes	3.2	(95-100)	3.60	1.73	1.73	n.a.	.27	n.a.
II.	High incidence in large cities								
2052	Biscuits and crackers	44.8	89.9	2.16	2.39	1.71	.74	.69	.16
2098	Macaroni and spaghetti	7.1	92.4	2.52	1.96	1.03	.77	1.74*	.21*
2099	Miscellaneous food preparations	72.0	80.8	2.03	2.14	1.61	.90	.46	.22
2331	Blouses	43.0	83.4	2.81	.75	.76	.84	1.34	.30
2342	Corsets and allied garments†	38.8	77.4	2.13	1.39	1.56	1.21	1.14	.22
2361	Children's dresses†	32.5	82.6	2.31	1.08	1.70	.87	1.01	.36
2369	Children's outerwear, n.e.c.†	30.6	78.6	2.66	.99	1.27	.97	1.17	.22
2386	Leather and sheeplined clothing	5.4	86.1	2.71	1.44	1.19	1.34	n.a.	n.a.
2393	Textile bags	12.1	92.7	2.60	2.90	1.22	.48	.10*	.07*
2399	Textile products, n.e.c.	18.0	82.8	2.61	1.25	2.00	.91	.52	.24
2514	Metal house furniture†	29.6	74.6	2.11	1.11	.71	2.02	.97	.20
2541	Partitions and fixtures	38.1	85.0	2.42	2.00	.83	.63	.57	.35
2563	Venetian blinds	9.4	87.1	2.41	2.15	1.49	.71	.75	.11
2691	Die cut paper and board	12.3	83.0	2.39	.70	.44	2.35	.94	.14
2751	Commercial printing†	200.2	86.2	2.50	1.87	1.31	.96	.67	.15
2782	Blank books and paper ruling	8.6	74.3	2.64	1.03	1.14	.38*	1.90*	n.a.
2842	Cleaning and polishing preparations†	18.0	93.3	2.07	1.55	1.92	.69	1.28	.29
2851	Paints and varnishes	56.6	96.0	2.58	1.97	.80	.95	.64	.17
2893	Toilet preparations†	24.8	92.4	2.49	1.16	1.86	.69	1.07	.27
2894	Glue and gelatin	6.8	88.4	2.05	.85	.31	2.12	.42*	.28*
3161	Luggage	15.9	88.8	2.57	2.46	.59	.64	.38	.24
3293	Gaskets and asbestos insulation	12.8	86.3	2.52	.46	.20	1.30	1.06	.50
3341	Secondary nonferrous metals†	15.8	95.7	2.21	1.17	.95	1.02	.51	.55
3411	Tin cans and other tinware	55.2	94.0	2.79	1.56	.68	.76	.47	.32
3463	Metal stampings†	128.2	83.7	2.24	1.28	.88	1.41	.82	.31
3468	Plating and polishing	36.1	84.7	2.50	1.59	1.17	1.15	.49	.25
3471	Lighting fixtures	45.1	76.0	2.68	.69	.81	1.44	.59	.35
3495	Screw machine products†	35.0	87.1	2.02	1.14	1.31	1.22	.90	.43
3499	Fabricated metal products, n.e.c.†	18.1	78.5	2.03	.86	.83	1.18	.80	.61
3565	Industrial trucks and tractors	15.8	75.8	2.32	1.02	.76	.88	.67	.58
3567	Industrial furnaces and ovens	8.4	86.9	2.25	1.79	1.49	.85*	n.a.	.26*
3591	Valves and fittings, except plumbing†	75.0	81.4	2.11	1.42	1.51	1.41	.91	.20
3592	Fabricated pipe and fittings†	12.7	89.4	2.19	.92	1.90	.71	1.32	.41
3699	Electrical products, n.e.c.	8.5	80.3	2.14	.70	2.05	.74*	.16*	.50
3811	Scientific instruments	45.3	96.0	2.26	1.14	.63	.34	.92	.71
3821	Mechanical measuring instruments	69.4	84.6	2.31	1.68	.73	.99	.64	.37
3911	Jewelry	23.5	95.0	2.24	2.58	.54	1.13	.12	.24
3963	Buttons	8.5	65.5	2.62	.90	n.a.	.93*	.76	.51
3981	Brooms and brushes	16.8	80.9	2.23	1.58	.73	1.29	.54	.35
3993	Signs and advertising displays	33.6	88.7	2.71	1.75	1.32	.85	.44	.17
3999	Miscellaneous products, n.e.c.	20.8	81.3	2.20	1.87	.32	1.50	.67	.24

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
III.	High incidence in medium cities, substantial in small								
2011	Meat packing plants	220.2	78.8	1.18	2.21	2.22	1.23	.26	.50
2027	Fluid milk and other products	177 3	70.2	1.17	2.00	1.78	1.46	.92	.40
2041	Flour and meal	29.0	58.3	.88	1.92	1.58	1.65	1.56	.36
2051	Bread and related products	246.3	82.9	1.99	2.47	1.66	1.20	.46	.12
2121	Cigars	38.5	88.2	1.23	3.19	2.31	.94	.64	.06
2515	Mattresses & bedsprings	32.1	93.1	2.19	2.63	2.88	.50	.08	.04
2522	Metal office furniture	16.1	70.5	.53	2.58	1.98	2.31	.60	27
2561	Window and door screens	4.4	79.3	1.39	2.95	.44	1.01	1.12	.33
2641	Paper coating and glazing	27.7	72.3	.73	2.15	2.22	1.15	.80	.61
2711	Newspapers	281.8	73.3	1.86	1.97	1.59	1.39	.98	.15
2896	Compressed and liquefied gases	10.4	90.1	1.58	2.89	1.34	.60*	.25*	.33
3011	Tires and inner tubes	92.7	86.0	n.a.	3.77	n.a.	1.55	n.a.	.38
3099	Rubber industries, n.e.c.	132.5	75.7	.68	2.53	1.24	1.50	1.18	.46
3192	Saddlery, harness, and whips	1.3	56.1	.65	3.25	.46	.84	2.38*	.26
3291	Abrasive products	22.3	88.6	1.09	1.78	2.63	.99	.27	.68
3351	Copper rolling and drawing	41 9	83.6	1.00	2.82	.90	1.93	.59	.16
3431	Plumbing fixtures and fittings	30.6	68.2	1.18	2.73	.71	1.31	.94	.39
3441	Structural and ornamental work	116.3	89.5	1.22	2.46	1.56	1.39	.64	.36
3443	Boiler shop products	74.4	83.8	.92	1.97	1.39	1.72	1.02	.45
3541	Machine tools	81.0	81.0	1.61	2.48	1.53	1.14	.87	.22
3571	Computing and related machines	56.7	85.0	.79	2.87	n.a.	2.75	n.a.	negl.
3585	Refrigeration machinery	128.3	77.5	.74	2.97	1.42	.91	.80	.55
3613	Electrical measuring instruments	33.0	88.8	1.06	2.26	4.59	.42	.20	.29
3614	Motors and generators	112.0	84.6	1 11	2.06	2.95	1.15	1.34	.24
3831	Optical instruments and lenses	12.7	97.4	1.05	3.97	.64	.64*	.06*	.48
3861	Photographic equipment	58.1	95.1	1.29	4.28	1.46	.72	.04	.12
3912	Jewelers' findings	5.4	98.5	52	3.97	n.a.	1.78*	n.a.	.23*
3961	Costume jewelry	27.7	98.4	2.23	3.40	.63	.96	.02	.07
IV.	High incidence in small cities, substantial in medium								
2034	Dehydrated fruits and vegetables	7.0	68.3	.28	1.53	2.70	1.28	2.23	.53
2081	Bottled soft drinks	91.6	64.0	1.15	1 99	1.86	1.87	1.14	.20
2131	Chewing and smoking tobacco	7.5	90.5	1.06	2.44	6.34	.42*	n.a.	n.a.
2397	Schiffli machine embroideries	5.7	98.1	1.14	.29	3.53	2.10*	1.60*	.23*
2431	Millwork plants	68.7	61.3	.84	1.63	1.37	2.06	1.23	.43
2532	Professional furniture	5.5	51.2	1.23	.40	1.12	3.76	.21*	.08*
2699	Paper and board products, n.e.c.	73.2	75.0	1.34	1.03	2.56	1.66	1.18	.35
2822	Intermediates and organic colors	32.7	70.0	.81	.32	.49	3.15	.24*	.69*
2932	By-product coke ovens	31.9	95.3	.80	1.31	2.19	2.24	.34	.54
3111	Leather tanning and finishing	43.5	65.2	1.11	1.06	.90	2.61	.85	.45
3131	Footwear cut stock	20.1	61.8	1.28	.38	3.02	2.34	.46	.45
3221	Glass containers	48.4	50.6	n.a.	.80	2.02	1.76	1.98	.50
3312	Steel works and rolling mills	518.7	93.5	.58	1.09	2.88	1.83	.60	.70
3321	Gray-iron foundries	133.9	68.4	.66	1.25	2.98	1.69	1.51	.45
3322	Malleable-iron foundries	23.4	52.1	.77	1.30	3.71	2.45	n.a.	n.a.
3323	Steel foundries	55.1	88.0	1.07	.86	3.31	1.50	1.41	.42
3391	Iron and steel forgings	39.8	92.3	1.38	1.16	2.59	2.16	.40	.32
3392	Wire drawing	54.9	80.4	.53	1.57	1.90	3.07	.47	.35

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
3442	Metal doors, sash and trim	43.3	81.9	1.74	1.69	1.17	1.87	.70	.24
3519	Internal combustion engines	51.8	59.5	1.30	.82	.59	3 76	.59	.03
3522	Farm machinery, except tractors	74.4	55.9	.54	1.03	1.41	2.53	2.00	.39
3531	Construction and mining machinery	75.7	77.9	1.02	1.87	2.63	1.75	.91	.28
3559	Special-industry machinery, n.e c.	47.0	78.7	1.12	1.90	1.03	2.42	.73	.28
3561	Pumps and compressors	60.3	72.4	.93	1.66	.97	2.45	.68	.44
3569	General industrial machinery, n.e.c.	27.9	85.6	1.13	1.41	1.85	1.96	.85	.42
3593	Ball and roller bearings	48.7	76.8	.99	1.92	1.98	2.31	.12	.18
3615	Transformers	41.0	89.7	.97	.58	4.10	3.12	.54	.09
3621	Electrical appliances	48.6	70.7	1.64	1.00	2.22	1.96	.64	.31
3662	Electronic tubes	71.0	67.2	.41	.76	2.98	2.34	1.88	.38
3717	Motor vehicles and parts	649.3	91.2	1.40	1.79	3.19	1.04	.69	.35
3729	Aircraft equipment, n.e.c.	180.9	90.8	1.10	1.67	1.44	1.61	.66	.58
3731	Ship building and repairing	109.5	80.0	1.37	1.58	2.14	1.88	.73	.06
V.	Wide incidence in all size cities, (a) over 2,500 and (b) over 10,000 population								
	(a) All size cities over 2,500 population								
2024	Ice cream and ices	36.5	75.7	1.98	1.75	1.68	1.19	1.03	.19
2031	Canned seafood	15.1	55.4	1.41	1.20	.80	1.08*	1.00*	.69
2035	Pickles and sauces	21.9	64.9	1.69	1.22	1.07	99	1.30	.57
2293	Paddings and upholstery filling	9.1	85.9	1.88	1.28	1.42	1.48	1.11	.30
2329	Men's and boys' clothing, n.e.c.	90.8	52.1	1.18	1.68	1.14	1.40	1.95	.35
2334	Dresses, dozen price	54.5	65.9	1.63	1.47	1.86	1.34	1.35	.28
2341	Women's and children's underwear	73.4	65.8	1.95	.94	.85	1.20	1.72	.40
2512	Household furniture, upholstered	56.0	64.4	1.31	1.58	1.14	1.56	1.80	.31
2531	Public building and related furniture	14.0	55.6	.84	1.91	1.03	1.47*	1.47*	.37
2671	Paperboard boxes	133.0	81.7	1.86	1.69	1.27	1.31	.76	.35
2899	Chemical products, n.e.c.	21.4	88.4	1.74	1.75	1.47	.87	.97	.45
3142	House slippers	10.9	62.1	1.42	.76	1.17	1.26	1.61*	.33*
3361	Nonferrous foundries	73.5	78.4	1.66	1.20	1.44	1.31	1.53	.37
3399	Primary metal industries, n.e.c.	25.1	94.1	1.48	.91	1.51	1.36	1.57	.50
3423	Hand tools, n.e.c.	23.4	63.4	1.04	1.39	1.80	1.66	1.03	.53
3439	Heating and cooking equipment, n.e.c.	75.3	75.6	1.57	1.47	1.46	1.69	.79	.38
3444	Sheet metal works	50.2	85.2	1.75	2.05	1.27	1.22	.90	.29
3489	Wirework, n.e.c.	59.9	82.8	1.94	1.06	1.46	1.45	.88	.40
3542	Metalworking machinery	59.5	80.6	1.31	1.40	2.20	.91	1.69	.44
3544	Special dies and tools	77.4	90.0	1.95	1.47	2.02	.96	.77	.40
3551	Food products machinery	33.2	75.5	1.92	.95	2.20	1.38	.89	.34
3563	Conveyors	32.4	78.9	1.49	.82	1.00	1.66	1.94	.40
3566	Power transmission equipment	49.6	83.2	1.92	1.87	1.19	.93	1.22	.30
3589	Service and household machines, n.e.c.	10.4	87.9	.97	1.16	2.68	1.47	.98*	.49
3594	Industrial patterns and molds	19.9	85.1	1.85	1.81	1.22	1.39	.77	.30
3599	Machine shops	103.7	77.1	1.69	1.19	1.20	1.42	.89	.50
3619	Electrical industrial apparatus, n.e.c.	15.0	76.3	.92	1.27	2.59	1.26	2.14	.37

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
3949	Sporting and athletic goods	28.9	64.8	1.55	1.11	.80	1.89	1.24	.41
3952	Lead pencils and crayons	5.0	69.5	1.62	1.25	1.27	n.a.	1.19*	.34
3971	Plastic products, n.e.c.	92.0	78.9	1.52	1.19	1.22	1.45	1.07	.53
3988	Morticians' goods	16.7	70.1	1.62	2.04	1.22	1.12	1.73	.19
(b)	All size cities over 10,000 population								
2097	Manufactured ice	20.9	55.4	.80	1.98	1.63	1.79	.30	.28
2295	Coated fabric, except rubberized	8.5	79.4	.91	1.64	1.25	1.83	.52*	.49*
2392	Housefurnishings, n.e.c.	36.2	56.9	1.99	1.01	.76	.95	.59	.72
2394	Canvas products	13.5	79.7	1.93	2.42	1.59	1.04	.56	.21
2732	Book printing	22.7	74.4	1.93	1.31	1.36	1.75	.19	.40
3429	Hardware, n.e.c.	88.3	85.8	1.50	1.48	2.25	1.01	.42	.60
3494	Bolts, nuts, washers, rivets	53.7	91.8	1.84	1.69	1.34	1.04	.70	.45
3553	Woodworking machinery	12.0	70.6	1.26	1.66	1.03	1.75	.65	.51
3564	Blowers and fans	18.1	87.8	1.59	1.66	1.80	2.01	.37	.25
3579	Office and store machines, n.e.c.	20.8	94.4	1.99	1.60	1.20	1.72	n.a.	n.a.
3611	Wiring devices and supplies	43.2	90.7	1.86	2.35	.78	1.18	.64	.30
3631	Insulated wire and cable	14.4	75.4	.85	1.96	2.08	1.05*	.38*	.48
3661	Radios and related products	294.0	82.0	1.90	1.38	1.37	1.32	.65	.42
3691	Storage batteries	15.7	88.6	1.67	1.57	2.25	1.63	.48*	.15*
3941	Games and toys, n.e.c.	38.2	85.4	1.69	1.50	1.68	1.13	.72	.49
3964	Needles, pins and fasteners	23.2	74.9	1.52	2.51	.75	1.79	.25	.30
VI.	High incidence in small cities outside metropolitan areas								
2015	Poultry dressing plants	46.2	29.9	.36	.78	.88	1.43	2.09	.96
2021	Creamery butter	21.0	23.2	.31	.78	.88	1.28	2.30	.98
2023	Concentrated milk	13.3	13.4	.06	.39	.37	1.41	3.39	.97
2033	Canned fruits and vegetables	119.8	46.7	.56	1.27	.66	1.34	1.91	.83
2036	Packaged seafood	12.2	38.6	.71	1.37	.46	1.66*	.77	.89
2037	Frozen fruits and vegetables	21.4	29.0	.11	.44	.19	1.88	2.27	1.07
2141	Tobacco stemming and redrying	18.8	46.1	n.a.	1.25	4.71	2.53*	1.46*	.17
2223	Thread mills	13.9	30.6	.41	.69	.64	2.07*	2.63	.38*
2224	Yarn mills, cotton system	85.3	15.8	n.a.	.22	1.07	1.47	2.64	1.06
2233	Cotton broad-woven fabrics	296.2	24.4	.08	.52	1.59	1.41	1.79	1.12
2234	Synthetic broad-woven fabrics	90.0	40.5	.18	.73	1.58	1.16	1.61	1.15
2252	Seamless hosiery mills	63.4	35.1	.15	.78	1.00	2.25	2.86	.58
2273	Carpets and rugs, except wool	11.5	32.3	.58	.54	.46	3.29	1.57	.49
2298	Cordage and twine	12.3	44.4	1.20	.72	n.a.	1.71	1.15*	.83
2321	Men's dress shirts and nightwear	108.3	45.0	.83	.95	1.27	1.66	2.55	.46
2382	Fabric work gloves	10.1	22.3	.27	1.09	n.a.	1.51	3.94*	.55
2432	Plywood plants	39.2	17.6	n.a.	.92	n.a.	2.07	1.68*	1.05
2444	Wooden boxes	39.5	39.0	.53	.86	1.10	1.34	2.11	.85
2511	Wood furniture, not upholstered	124.9	42.0	.64	1.08	1.32	1.72	2.31	.54
2611	Pulp mills	57.7	21.6	n.a.	.36	.44	1.49	2.40	1.14
2612	Paper and paperboard mills	142.2	43.3	.14	.55	1.36	1.69	1.95	1.00
2613	Building paper and board mills	16.4	50.0	.18	.88	.78	1.79	2.00	.92
2872	Fertilizers, mixing only	12.0	47.5	.35	1.11	.95	1.53	1.70	.92
2881	Cottonseed oil mills	13.7	37.6	n.a.	1.29	1.81	1.85	2.41	.59
3141	Footwear, except rubber	219.4	43.7	.80	.41	1.92	2.18	2.09	.47
3229	Pressed and blown glassware, n.e.c.	41.9	32.7	.18	.32	.34	3.61	1.96	.55

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
3255	Clay refractories	14.5	38.6	.49	n.a.	.39	1.75	1.36	1.15
3275	Mineral wool	10.2	42.4	.16	1.27	.53	3.57	.26	.29
3281	Cut-stone and stone products	21.6	36.9	.58	.86	.49	2.07	1.25	.88
3581	Domestic laundry equipment	22.1	40.5	n.a.	1.13	n.a.	2.65	2.36	.06
3641	Engine electrical equipment	46.3	39.2	.43	1.80	.08	3.28	1.80	.20
VII.	High incidence in smallest cities								
2222	Yarn throwing mills	11.8	58.8	.73	.84	1.54	1.90	2.15	.51
2251	Full-fashioned hosiery mills	60.2	51.6	.46	.92	1.15	1.52	3.12	.57
2254	Knit underwear mills	31.3	57.9	.46	1.36	2.44	1.06	3.09	.41
2256	Knit fabric mills	16.8	58.3	.86	.98	1.03	1.34	2.39	.62
2322	Men's and boys' underwear	9.4	25.2	.31	.47	n.a.	1.99*	2.69*	.61
2327	Separate trousers	51.7	53.0	1.26	1.10	.68	1.23	2.41	.50
2328	Work shirts‡	7.0	16.7	.07	n.a.	n.a.	.58*	5.50*	.53*
2441	Fruit and vegetable baskets	6.7	20.9	.07	.24	n.a.	1.29	2.23*	1.17
2521	Wood office furniture	5.5	61.4	99	1.09	.22	1.48	3.42	36
2674	Fiber cans, tubes, and drums	12.1	71.7	1.20	1.44	1.68	1.34	2.07	.33
2889	Animal oils, n.e.c.	2.3	29.0	.43	.31	.42	.69	3.18	1.11
2952	Roofing felts and coatings	15.7	92.7	1.06	1.31	1.17	96	2.70	.47
3152	Leather work gloves	2.5	35.7	1 06	.98	n.a.	1.09*	3.10	.49
3269	Pottery products, n.e.c.	9.6	60.9	.62	.84	.61	1.45	2.69	.72
3292	Asbestos products	22.0	86.8	1.07	.31	.80	.77	2.33	.96
3521	Tractors	64.7	92.6	1.05	43	2.93	1.37	3.25	.21
3713	Truck and bus bodies	18.7	56.8	1.02	1.06	1.47	1.73	2.60	.29
3722	Aircraft engines	167.4	96.5	.94	.51	.66	.86	2.26	.96
VIII.	Wide incidence in non-urban as well as urban places								
2026	Fluid milk	14.1	59.2	.71	.89	1.07	1.27	1.22	1.00
2241	Narrow fabric mills	25.7	66.7	.83	1.11	2.64	1.09	1.04	.77
2261	Finishing textiles, except wool	79.3	59.6	.45	1.27	1.66	1.23	.91	1.01
2499	Wood products, n.e.c.	38.6	39.3	.59	.80	.71	1.20	1.80	1.02
2661	Paper bags	33.3	69.7	1.35	1.22	.92	.95	.82	.86
2871	Fertilizers	19.7	73.3	.59	1.52	1.12	1.26	.64	1.01
2886	Grease and tallow	11.5	73.8	1.61	1.31	1.17	.76	.54	.81
2951	Paving mixtures and blocks	4.4	72.1	.76	1.04	.76	1.63	.98	.92
3295	Minerals, ground or treated	7.7	76.9	.76	1.25	1.59	1.06	.54	1.04
3297	Nonclay refractories	8.6	67.3	1.05	n.a.	1.32	.74	1.21*	1.06
3491	Metal barrels, drums, and pails	10.6	96.1	1.41	.92	1.49	1.38	.40*	.75*
3545	Metal working machinery attachments	44.9	79.4	1.60	.92	1.49	1.04	.62	.77
IX.	High incidence in non-urban places								
	(a) Within metropolitan areas								
2084	Wines and brandy	5.7	62.9	.85	.24	.39	.64	.68	1.57
2819	Inorganic chemicals, n.e.c.‡	97.0	61.1	.30	.25	.95	.74	.29	1.78
2824	Synthetic rubber§	8.5	88.5	n.a.	.84	negl.	n.a.	n.a.	1.39*
2829	Organic chemicals, n.e.c.	67.5	74.5	.36	.28	1.19	1.36	.51	1.45
3241	Cement, hydraulic§	39.8	56.1	.37	.86	n.a.	n.a.	.87	1.50
3352	Aluminum rolling and drawing§	36.8	66.3	.37	.25	n.a.	.79*	.15*	1.28

Table B-2 (continued)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
	(b) Outside metropolitan areas								
2022	Natural cheese	13.9	13.8	.25	.25	.19	.82	2.08	1.46
2061	Raw cane sugar	3.1	0.0	0	0	0	n.a.	n.a.	2.18
2063	Beet sugar	11.0	12.9	0	0	0	n.a.	n.a.	2.28
2411	Logging camps and contractors	75.5	6.3	.01	.05	.03	.34	.71	2.13
2421	Sawmills and planing mills	321.2	10.8	.02	.33	.12	.61	1.13	1.83
2422	Veneer mills	12.8	20.8	n.a.	.76	.68	1.09	1.88*	1.25
2423	Shingle mills	2.5	24.7	n.a.	1.22	negl.	1.20*	1.15	1.39
2424	Cooperage stock mills	3.4	10.2	n.a.	.36	negl.	1.52*	1 34*	1.47
2433	Prefabricated wood products	11.5	48.7	.34	1.09	1.12	.79	1.24	1.25
2491	Wood preserving	12.1	43.3	.25	.86	.46	1.10	1.55	1.28
2825	Synthetic fibers§	61.1	33.7	n.a.	n.a.	n.a.	n.a.	n.a.	1.83
2826	Explosives§	32.5	49.7	n.a.	n.a.	n.a.	n a.	n.a.	1.68
3251	Brick and hollow tile	32.4	46.8	.14	.58	.75	.79	.90	1.62
3254	Clay sewer pipe	9.6	29.2	.19	.49	.47	.66*	2.11*	1.32
3259	Structural clay products, n.e.c.	5.0	27.7	.24	.33	.02	.47*	.75*	1.79
3272	Gypsum products	11.0	47.7	.85	.43	n.a.	.69*	n.a.	1.52
3274	Lime	8.0	16.9	n.a.	.16	n.a.	.23	.53	2.11
X.	Industries which do not meet criteria for the above categories								
2025	Special dairy products	7 3	53.7	1.39	.14	.88	.93	2.76	.71
2042	Prepared animal feeds	59.9	56.1	.66	1.70	1.85	1.24	1.53	.62
2085	Distilled liquor	21.5	61.4	1.01	1.69	n.a.	.36*	n.a.	1.18
2093	Margarine	2.6	77.5	1.85	3.41	0	n.a.	n.a.	.55*
2211	Scouring and combing plants	7.0	71.3	.65	n.a.	3.46	n.a.	n.a.	1.42
2212	Yarn mills, wool, except carpet	17.8	55.0	.25	66	4.27	.36*	1.58	.98
2213	Woolen and worsted fabrics	62.5	45.8	.40	.43	1.53	.54*	1.08*	1.25
2281	Fur-felt hats and hat bodies	8.2	59.9	1.55	57	n.a.	4.11	n.a.	.12
2294	Processed textile waste	5.8	76.5	1.35	.92	n.a.	2.11	.38*	.60
2381	Fabric dress gloves	4.5	41.7	1 62	.54	n.a.	2.78	1.64*	.21
2445	Cooperage	3.7	75.3	1.48	3.04	.51	.42	.82	.51
2823	Plastics materials	41.1	71.7	.39	1.10	.46	1.79	.42	1.18
2834	Pharmaceutical preparations	76.6	90.2	1.88	.88	.63	1.25	1.09	.60
2841	Soap and glycerin	25.8	99.2	1.72	3.41	1.14	.20	1.46	.14
2897	Insecticides and fungicides	6.5	78.6	.46	1.42	1.47	.60	1.23	1.12
2911	Petroleum refining	153.1	78.8	.58	.30	1.76	1.09	1.24	1.19
2992	Lubricants, n.e.c.	8.2	94.0	1.77	2.89	.76	.56	.30	.48
3231	Products of purchased glass	21.6	65.9	1.84	1.36	.46	.89	.97	.65
3261	Vitreous plumbing fixtures	9.2	54.5	n.a.	1.76	n.a.	1.58	1.98*	.70
3271	Concrete products	60.4	65.0	.49	1.31	1.64	1.45	1.30	.82
3421	Cutlery	15.1	71.7	1.58	2.26	.31	1.27	.81	.45
3422	Edge tools	7.1	76.9	1.71	1.70	2.81	.45	1.06	.40
3493	Steel springs	7.1	92.0	1.72	1.49	.17	2.20*	.94*	.09*
3532	Oil-field machinery and tools	33.7	78.8	1.95	1.86	.51	1.01*	.09*	.43
3552	Textile machinery	36.6	59.8	.56	1.36	1.58	1.58	1.43	.71
3554	Paper-industries machinery	15.0	59.5	.79	1.26	1.93	2.66	.95	.34

Table B-2 (concluded)

SIC 1954	Industry Title	Total Industry Employment 1954 (000)	Percent Within SMAs	Location Quotient for Places with 1950 Population of: 500,000 or more	100,000-499,999	50,000-99,999	10,000-49,999	2,500-9,999	All Other
3715	Truck trailers	16.4	87.5	1.23	2.27	n.a.	25*	2.52	.37
3716	Automobile trailers	11.1	50.4	.50	.48	.73	1.44	1.68	1.10
3732	Boat building and repairing	16.9	51.2	.43	1.19	.58	1.42	1.90	.90
3799	Transportation equipment, n.e.c.	1.6	61.3	.36	.91	4.53	1.49*	.47*	.53

n.a = not available.
negl = negligible, less than .005
n.e.c. = not elsewhere classified

* Represents part but not all of the industry's employment in this size group because data for some cities is not available.
† Also well distributed in other size cities.
‡ Distribution of over 10 percent of this industry's employment is not available.
§ This industry meets the criterion of having 50 percent or more of total industry employment in non-urban places, though the city-size distribution for more than 10 percent of employment is not available.

Source Based on U.S Dept of Commerce, Business and Defense Services Administration, Office of Area Development, Metropolitan Area and City Size Patterns of Manufacturing Industries 1954, Area Trend Series No 4, Washington, D C., June 1959, pp. 12-21. For detailed criteria see p. 377.

Appendix C

INCREMENTAL INFRASTRUCTURE COST ESTIMATION

Table C-1

ESTIMATED GROWTH IN NET OUTPUT
SELECTED INDIAN INDUSTRIES, 1965-66 TO 1975-76

Industry	Value Added* (Rs. million) 1965-66	1975-76	Projected Increase (%)
Vegetable oils	302†	602	99%
Woolen fabrics	43	328	663
Cotton yarn	711	1,602	125
Paper and paper board	235	714	204
Alcohol	10	20	100
Pesticides, fungicides, and weedicides	17	209	1,129
Drugs and pharmaceuticals	495	1,155	133
Plastics	35	348	894
Paints and varnishes	51	179	251
Soap	104	255	145
Steel castings & forgings	18	276	1,433
Steel pipes and tubes	54	336	522
Grey iron castings	47	337	617
Cast iron pipes	42	310	638
Steel structural fabrication	8	61	663
Hurricane lanterns	4	9	125
Steel furniture	19	69	263
Utensils	37	98	165
Electric motors (below 150 kw)	44	189	330
Control gears and switchgear	68	300	342
Air conditioners	13	131	908
Electric fans	50	202	304
Domestic refrigerators	21	135	543
Electronic measuring and testing instruments	n.a.‡	60	--
Transmitters and industrial electronic equipment	n.a.‡	270	--
Radio receivers	38	174	358
Motorcycles and scooters	21	95	352
Automobile ancillaries	196	600	206
Bicycles complete	61	172	182
Bicycle parts	48	150	213
Sugar machinery	23	75	226
Diesel engines (stationary)	76	246	224
Power driven pumps	208	438	111
Machine tools	120	656	447
Air compressors	10	73	630
Precision, surgical and mathematical instruments	41	460	1,022
Bolts, nuts and rivets	24	85	254
Sewing machines	24	99	313
Total	3,318	11,518	247

* Value added in 1960-61 prices.
† 1964-65. Vegetable oils value added estimated from value of production.
‡ Assumed negligible.

Source: Government of India, Planning Commission, Perspective Planning Division, Draft Fourth Plan, Material and Financial Balances: 1964-65, 1970-71, 1975-76, Simla, September 1966.

Table C-2

DESIGN STANDARDS FOR UTILITIES, SERVICES, AND ROADS

Water:

Industry Area

Additional requirements apart from industry use:	Gallons Per Capita Per Day
Workers' personal use	8
Civic use	7
Total	15

Housing Area

Per capita supply	30-40*

Design of Overhead Water Tanks (OHT)

Holding capacity	two hours of peak supply†

Sewerage

- All industry and housing areas to be provided underground sewerage.
- Industry liquid waste to be treated on plot before discharged into sewers and to conform to Indian standard tolerance limits (IS:3306-1965).
- Disposal works to consist of screening chambers, settling tanks where applicable.
- 90 percent of industry water consumed reckoned as sewage flow.
- 80 percent of per capita water supply reckoned as sewage flow in housing areas.
- Design criterion: Three times dry weather flow (DWF) is the peak.

Table C-2 (Concluded)

Roads

Carriage Lane	Right of Way (ROW)
2 lanes (20')	60 feet
3 lanes (27')	80 feet
4 lanes (32')	100 feet

Power:

Housing Area:

- 100 watts per industrial worker. Assumes 10 percent of supply for public uses, plus 100 watts per dwelling unit

Industry Area

- Supply for public use being negligible as compared to industry supply, no separate provision is assumed.

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* In cities A, B, & C @ 30 gpcd; cities D & E @ 40 gpcd.

† For fire protection services, 1/3 holding capacity is reserved in OHT.

Table C-3

DESIGN STANDARDS FOR HOUSING AREA

A. Density

Gross Density (dwellings per acre)

No. of Stories	Dwellings Per Acre
2	30
3	30 to 40
4	30 to 45

5 Test Cities:

Gross density to be achieved . . . 30 dwellings per acre

No. of Stories	Net Residential Density
2	370-380 persons per acre
4	500 persons per acre

B. Ratio of Worker to Household

- One industrial worker per household
- One household to have five persons

C. Parks, Open Spaces, and Other Community Facilities

Parks and open spaces . . . . 1 to 1.5 acres per 1,000 persons

Shops . . . . . 1 to 1.5 acres per 10,000 persons

(2 shops per 150 persons and 3 commercial places per 10,000 persons)

Public and Community Facilities.* (religious, libraries, community center, etc.) . . . . . 1.5 acres (minimum per 1,000 persons)

Table C-3 (Concluded)

D. Houses

Percent employees to be provided with dwelling houses . . . . . 20 percent

Plinth Area:

Income Range	Plinth Area (sq ft)
Less than Rs. 100 per month	350
Between Rs. 100 to 200 per month .	400
Between Rs. 200 to 300 per month .	450
Rs. 300 and above per month	500

E. Service Population:

While providing housing for industrial workers the need for service population is recognized, but in view of the difficulty of establishing a statistical relation (for population multiplier) to industrial workers in different city sizes, this aspect has not been taken into account for cost estimates. By definition of cost, service population would not be within the scope of the project. (See pages 29 and 346.)

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* For standards on schools and hospitals see corresponding sections in Chapter III.

Table C-4

DESIGN STANDARDS FOR INDUSTRY AREAS

Plinth Area	1.25 floor area
Plot Coverage by Buildings	45 percent of plot area

Land Requirements:

Area under:	Range (percent)
Industry plots	60 to 70
Roads, streets, and parking	12 to 15
Rail sidings	3 to 4
Utilities and services (tubewell site, electric substation, etc.)	3 to 4
Public use:	
Administrative offices, shops, canteens, dispensaries, etc	3 to 4
Parks and open spaces	8 to 10
Warehousing (includes transport agency booths)	1 to 3

Minimum efficiency of industry area	65 percent

Table C-5

ON-SITE RAILROAD REQUIREMENTS IN INDUSTRY AREAS - FIVE TEST CITIES

Design Criteria for Number of Cars and Size of Goods Sheds

- 52.5 percent of total tonnage by rail terminates on site of industry area
- Average permissible load per car - 20 tons
- Length of track per car - 30 ft
- Area of covered goods shed per car - 100 ft
- Area of uncovered goods shed - 1/3 of covered shed
- Length of platform - 800-1,000 ft per siding

Table C-6

WATER SUPPLY IN INDUSTRY AND HOUSING AREAS - FIVE TEST CITIES

	Design Criteria and Number of Tubewells, OHT				
City Size	A	B	C	D	E
A. Design Standards:					
Tubewell Assembly Code (twa)	← 27/15/8 →				
Depth in feet	300	300	300	350	350
Lifthead for Pumps (ft)	130	130	130	130	130
Pump Efficiency	← 65 percent →				
OHT Staging Height (ft)	← 70 →				
B. Requirements:					
Water (gph)	38,900	107,900	140,400	294,200	1,164,900
Number of Tubewells	2	5	5	10	36
Rated Capacity for Pumping Machinery (gph)	25,000	30,000	40,000	42,000	46,000
OHT Capacity (000 gal)	80	100/120	150	100/200	80/150/200
Number	1	1 / 1	2	2 / 2	1/ 3 / 9

ADDITIONAL COST DATA

1. Rail Spur (Broad Gauge)*

Length of track: 3270 yards. Ludhiana - 1966

	Rs.
Supplying and laying track	
90/BSS over timber chair sleepers	402,077
Cost of work to be carried out inside railway premises	63,249
Cost of structural work carried out inside the firm	39,796
Erection charges	48,686
Cost of signals and interlocking	29,295
Overheads	95,036
Total	678,139

i.e., Rs. 69.12 per sq ft

Adjusted cost (Bareilly - 1967) = Rs. 83 per sq ft

2. Goods, Sheds, Platforms, etc.

	Unit Cost (Rs. per sq ft)
B-Class goods sheds:	
Covered area	9.0
Uncovered area	6.0
B-Class platform (uncovered)	6.0

* Rail spur cost does not include cost of land or embankment.

Source: Field studies. Norms of B-Class goods sheds by Northern Railway.

Table C-7 (concluded)

Road Appurtenances

	Total Cost (Rs.)
1. Pedestrian over bridges:	
Bridge of timber and steel with side stair cases; clear width 12 ft, span 210 ft, minimum clear height as per Indian Standards	230,000
or unit cost (per sq ft of span area)	91.25
2. Traffic signals:	
Electrically operated controlled signals, at road intersections, complete with three aspect signal heads, master control panel and cables (1 set)	53,000
3. Cycle tracks:	
9 ft wide track with curb stone, 3/4-in. premix carpet over 3-in. aggregate (per 100 ft)	67.35

Note: Cost for projects completed in 1967. Includes costs of erection and overheads.

Source: Municipal Corporation of Delhi, Delhi.

Table C-8

SERVICE LIFE AND CAPITAL RECOVERY FACTORS
FOR URBAN FACILITIES AND ELEMENTS

Facility and Element	Service Life (years)	Capital Recovery Factor @ 10%	Capital Recovery Factor @ 5%
Site development, excl. roads			
Street lighting	35	.10369	.06107
Other	100	.10001	.05038
Roads			
Roads, cycle tracks, pedestrian bridges	18	.12193	.08555
Traffic signals	25	.11017	.07095
Rail			
Track	25	.11017	.07095
Platforms and sheds	50	.10086	.05478
Power			
Distribution mains	40	.10226	.05828
Substations			
Transformers and installations	35	.10369	.06107
Switchgear	25	.11017	.07095
Underground lines	40	.10226	.05828
Sewerage			
Disposal plants incl. pumping	35	.10369	.06107
Lines - trunks	65	.10020	.05219
Water			
Tubewells	30	.10608	.06505
Pumping machinery	25	.11017	.07095
Pump chamber	50	.10086	.05478
Overhead water tanks	65	.10020	.05219
Pipeline	50	.10086	.05478
Houses	50	.10086	.05478
Schools			
Building	50	.10086	.05478
Equipment	20	.11746	.08024
Hospitals			
Building	50	.10086	.05478
Equipment	20	.11746	.08024
Fire	10	.16275	.12950
Police	50	.10086	.05478

ANNOTATED BIBLIOGRAPHY

The focus of this bibliography is on materials useful to the study of industrial infrastructure costs in relation to city size, in a regional development context. The intent is selective, not inclusive. Relevance of materials to the central subject of this study is the principal selection criterion. General references on city planning, regional and industrial development, or engineering are included only if they contain specific material on costs or on methods of analysis used in this study. Works cited in the text are included to the degree they serve as a substantial working reference of general interest in the subject field.

Works are numbered consecutively throughout the bibliography but listed alphabetically within each of five subject categories:

I. Regional Development and City Size

II. Analysis of Urban Infrastructure Costs as Related to City Size

III. Costs of Individual Facilities and Services

IV. Industrial Location and Infrastructure Requirements

V. Policies, Program Measures, and Analytical Techniques

I. Regional Development and City Size

1. Ahmad, Qazi S., Indian Cities: Characteristics and Correlates, University of Chicago, Department of Geography, Chicago, 1965.

   A pioneering study of cities in a developing country, utilizing latest statistical and analytical techniques with respect to 62 variables to provide insight into major characteristics of Indian cities. Concludes that city size plays a significant role in India's urban system. Large urban centers are characterized among other things by relatively large areas, greater generalized accessibility, greater accessibility to the railroad network, and a high proportion of in-migrants. The major metropolitan centers, though having high accessibility, do not have the same high concentration of manufacturing activity in terms of the proportion of total labor of the city as is found in more industrialized countries.

2. Berry, Brian J. L., and Allen Pred, Central Place Studies - A Bibliography of Theory and Applications, including Supplement through 1964 by H. G. Barnum, R. Kasperson, and S. Kiuchi, Bibliography Series No. 1, Regional Science Research Institute, Philadelphia, 1965, 153 pp.

   A brief essay on central place theory and an abstract of Walter Christaller's theoretical work introduce this comprehensive bibliography and set the pattern for its table of contents. Succinct, authoritative annotations.

3. Christaller, Walter, Central Places in Southern Germany, trans. by Carlisle W. Baskin, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1966.

   A translation of the classic statement of central place theory. The concepts of hierarchy of urban size, function, and market area are developed and related to the pattern of central places in southern Germany.

4. Fisher, Jack C. (ed.), City and Regional Planning in Poland, Cornell University Press, Ithaca, N.Y., 1966, 491 pp.

   Major presentation of papers by Polish scholars and planners on the history, theory, and current practice of urban and regional planning in a socialist economy.

5. Friedmann, John, Regional Development Policy: A Case Study of Venezuela, The M.I.T. Press, Cambridge, Mass., 1966, 279 pp.

   Basic formulation of goals and policy approaches for spatial organization. Sees the need for regional policy as arising during the transition of national economies to industrialism. Center-periphery relations typify a case of spatial disequilibrium, requiring counteracting development policies. An integrated approach to the development of core regions, resource frontiers, and development corridors is illustrated from planning experience in Venezuela.

6. Friedmann, John, The Spatial Structure of Economic Development in the Tennessee Valley: A Study in Regional Planning, The University of Chicago Press, Chicago, Ill., March 1955, 187 pp.

An important study which relates spatial structure to development in the Tennessee Valley Authority area during the years 1930 to 1950.

7. Friedmann, John, and William Alonso, Regional Development and Planning: A Reader, The M.I.T. Press, Cambridge, Mass., 1964, 722 pp.

A fundamental volume which brings together important articles on regional development theory and policy, location, and spatial organization. Papers of particular relevance to the present study include: Brian J. L. Berry, "City Size Distributions and Economic Development;" Edward L. Ullman, "Regional Development and the Geography of Concentration;" Richard L. Morrill, "The Development of Spatial Distributions of Towns in Sweden: An Historical-Predictive Approach;" and William H. Nicholls, "Industrialization, Factor Markets, and Agricultural Development."

8. Green, F.H.W., "Community of Interest Areas - Notes on the Hierarchy of Central Places and Their Hinterlands," Economic Geography, Vol. 34, No. 3, July 1958, pp. 210-226

Summarizes Losch's thesis that each individual product or service has an optimum marketing area determined primarily on a profits basis. A whole region will be covered with marketing areas which assume a hexagonal shape. The author applies to Great Britain the concepts of five orders of centers: (1) metropolis (London), (2) provincial capitals (Aberdeen), (3) towns of varying characteristics and hinterlands, (4) district centers (10-20 miles apart), and (5) the "service village."

9. Hauser, Philip M., and Leo F. Schnore, The Study of Urbanization, John Wiley & Sons, Inc., New York, 1965, 554 pp.

A comprehensive set of essays on urban research. Particularly useful for studies of urban areas in less developed countries are the following chapters: Philip M. Hauser, "Urbanization: an Overview;" Raymond Vernon and Edgar M. Hoover, "Economic Aspects of Urban Research;" Gideon Sjoberg, "Cities in Developing and in Industrial Societies: A Cross-cultural Analysis;" Norton S. Ginsburg, "Urban Geography and 'Non-Western' Areas;" and Leo F. Schnore, "On the Spatial Structure of Cities in the Two Americas."

10. Herrick, Bruce H., Urban Migration and Economic Development in Chile, The M.I.T. Press, Cambridge, Mass., 1965, 126 pp.

A study of the Chilean economy from 1940 to 1960 which the author notes is an "interesting example of a country in which incipient tendencies toward economic development decayed into stagnation and in which urban migration assumed a form reflecting the economic and demographic conditions surrounding it." The book finds the

Chilean Development Corporation's decentralizing tendencies in sharp contrast to the government's public school and public housing spending. The author concludes: "the task for the economy now is the creation of employment opportunities in modern industrial plants within existing urban centers - plants that would more effectively use the labor resources already located in these centers . . . Although the elasticity of movement in response to the creation of infrastructure capital is uncertain, it was clear that public housing programs were more concentrated in the largest cities than in the outlying districts . . . this concentration would encourage further migration to these cities."

11. Isard, Walter, Location and Space Economy, John Wiley & Sons Inc., New York, 1956, 350 pp.

Fundamental elaboration and integration of theories of location, production, and trade. Emphasizes transport inputs, locational equilibrium of the firm, market and supply areas, and urbanization. In discussing agglomeration, illustrates hypothetical economies and diseconomies of scale as a function of urban size.

12. Jakobson, Leo, and Ved Prakash, "Urbanization and Regional Planning in India," Urban Affairs Quarterly, Vol. II, No. 3, March 1967, pp. 36-65

Review and critique of proposals for decentralized industrialization and urbanization in India. The authors propose an alternative view of urbanization: "not in the context of dispersed growth nodes each having its own small area of influence, but in the light of integrated linear systems in which each node interacts with others along efficient, rapid, multipurpose transportation corridors. The linear system in its entirety would, in our hypothesis, perform the role of counter-magnetism vis-a-vis the metropolis."

13. Johnson, E.A.J., Market Towns and Spatial Development in India, edited by the National Council for Applied Economic Research, 1965, 162 pp.

Important contribution to understanding the role of regional market and production centers in economic development. Provides valuable data and analyses with respect to public or government-supported infrastructural requirements in rural market centers, stressing commercial fertilizer mixing and storage facilities, power connections, water filtration plants, sewer and sanitation systems, connecting roads, and multipurpose schools. The main analysis is concerned with the establishment of, and need for, agricultural warehouses in strategically located "intermediate urban centers," supplemented by sub-depots.

14. Lewis, John P., Quiet Crisis in India--Economic Development and American Policy, The Brookings Institution, Washington, D.C., 1962, 350 pp.

Detailed examination of major issues of planning and plan implementation in India. A key chapter on locational strategies recommends concentrating more industrial development efforts in towns of 20,000 to 300,000 and less in both larger cities and smaller village areas. This is coupled with a suggestion for utilizing surplus labor in labor-intensive activities to create infrastructure in towns, villages, and rural areas.

15. Meyer, John R., "Regional Economics: A Survey," The American Economic Review, Vol. LIII, No. 1, Part I, March 1963, pp. 19-54

Wide-ranging review of state of the art in regional economics. Thorough bibliography.

16. Milone, Pauline Dublin, Urban Areas in Indonesia: Administrative and Census Concepts, University of California, Institute of International Studies, Research Series No. 10, Berkeley, 1966, 225 pp.

A collection of information on all Indonesian cities and towns and on the functions these urban areas performed both in the past and in the present. Indonesia has no single primate city but a system of cities each with its own function.

17. Pitts, Forrest R. (ed.), Urban Systems and Economic Development, University of Oregon, School of Business Administration, Eugene, June 1962, 94 pp.

Papers and proceedings of a conference of urban geographers held at the University of Oregon in December 1959. Included are: Brian J. L. Berry, "Some Relations of Urbanization and Basic Patterns of Economic Development;" William L. Garrison, "Intra- and Interurban Transportation Networks;" and Robert C. Mayfield, "An Urban Research Study in North India."

18. Powelson, John P., and Anatole A. Solow, "Urban and Rural Development in Latin America," American Academy of Political and Social Science Annals, Vol. 360, July 1965, pp. 48-62

Population growth is resulting in flow to urban areas at a faster rate than can be absorbed by facilities or jobs. Briefly discusses problem of urban investment choice between main large centers and small or medium centers or new towns. Examples in Brazil, Central America and Puerto Rico are cited. Concludes policy should encourage growth of medium sized centers.

19. Rivkin, Malcolm D., Area Development for National Growth: The Turkish Precedent, Frederick A. Praeger, Publishers, New York, 1965, 225 pp.

Concludes that for Turkey "area development efforts are most effective when made on a selective, concentrated basis in peripheral

regions of high growth potential and that the commitment to extend modernization beyond national centers involves a corollary commitment to guide the selected regions continually through the growth process."

20. Sovani, N. V., Urbanization and Urban India, Asia Publishing House, Bombay and New York, 1966, 157 pp.

Significant collection of research essays by the author, including critique of the concept of "over-urbanization" and analyses of housing, occupational mobility, and changes in the structure of urban incomes.

21. Thompson, Wilbur R., A Preface to Urban Economics, Resources for the Future, Inc., published by The Johns Hopkins Press, Baltimore, Md., 1965, 413 pp.

Basic, comprehensive discussion of goals, processes, problems, and policy in the field of urban economics. Shows how a local economy changes from one export base to another with maturity, rising incomes, and technological progress. Examines relationships between urban centers and the local or national environment, urban-regional growth and possible resultant diseconomies of scale, and the "export-base" theory. Concludes that to be viable, small towns or cities must be linked economically to larger urban areas comprising, under present U.S. circumstances, a minimum community of 300,000. Presents many excellent ideas relating to infrastructural requirements and costs.

22. Turner, Roy (ed.), India's Urban Future, selected studies from an international conference, June 26-July 2, 1960, Berkeley, sponsored by Kingsley Davis, Richard L. Park, and Catherine Bauer Wurster, University of California Press, Berkeley and Los Angeles, 1962, 470 pp.

A basic reference book for industrial development and urban planning in developing countries. Papers especially helpful to a study of urban industrial infrastructure are: Shanti Tangri, "Urbanization, Political Stability, and Economic Growth;" William Bredo, "Industrial Decentralization in India;" Britton Harris, "Urban Centralization and Planned Development;" Catherine Bauer Wurster, "Urban Living Conditions, Overhead Costs, and the Development Pattern;" S. G. Barve, "Urbanization in Maharashtra State: Problems and a Plan of Action;" and Albert Mayer, "Some Operational Problems in Urban and Regional Planning and Development."

23. United Nations Economic and Social Council, World Survey of Urban and Rural Population Growth: Preliminary Report by the Secretary-General, E/CN.9/187, March 8, 1965, 24 pp., mimeo

An excellent summary of degrees and patterns of urbanization in 90 countries from 1950 to 1960. Urban population is defined, for purposes of international comparison, as the population living in localities of 20,000 or more inhabitants. Generally, the level of

urbanization in the more developed regions is at least twice as high as that in less developed regions.

24. Vernon, Raymond, Metropolis 1985: an Interpretation of the Findings of the New York Metropolitan Region Study, Harvard University Press, Cambridge, Mass., 1960, 252 pp.

This book deals with the New York Metropolitan Region's total employment performance, finding it a net product of two countervailing tendencies: a strong "mix" and a weak competitive position. Summarizes the series of reports resulting from the New York Metropolitan Region Study.

II. Analysis of Urban Infrastructure Costs as Related to City Size

25. Abrams, Charles, Man's Struggle for Shelter in an Urbanizing World, The M.I.T. Press, Cambridge, Mass., 1964, 307 pp.

This study summarizes the findings of the author in the course of work in Asia, Europe, and Latin America. Contains valuable suggestions and hypotheses pertinent to the study of industrial location and urban infrastructure, including discussion of industrial versus planning interests, expansion of existing towns versus new towns, factors influencing location of industry, inefficacy of standard remedies for housing problems, need for practical devices to reduce costs, and urban land reform.

26. Alonso, William, Location and Land Use: Toward a General Theory of Land Rent, Harvard University Press, Cambridge, Mass., 1964, 204 pp.

A sophisticated, fundamental study on the economics of urban land.

27. Bartholomew, Harland, Land Uses in American Cities, Harvard City Planning Studies XV, Harvard University Press, Cambridge, Mass., 1955.

Discusses the percentage of land used for residential and industrial purposes (including light and heavy industry), railroad property, streets, parks and playgrounds, public and semi-public property, and left vacant. Examines relationships between per capita use of land and city growth; percentage of land absorbed by light industry and city population; light manufacturing processes and location in peripheral or central areas. Presents data for various sizes of cities, satellite towns, and urban areas.

28. Bollens, John C. (ed.), Exploring the Metropolitan Community, University of California Press, Berkeley and Los Angeles, 1964, 643 pp.

Case study of the St. Louis metropolitan area. Its broad scope covers major social, economic, and government characteristics. Methods and results are given for inquiries on factors affecting per capita expenditure levels and minimum standards of public education in primary and secondary schools, fire and police protection,

refuse collection, and street service. No major economies or diseconomies of scale were found.

29. Brazer, Harvey E., City Expenditures in the United States, National Bureau of Economic Research, Inc., Occasional Paper No. 66, New York, 1959, 82 pp.

A basic study of urban per capita expenditures of 462 cities in the United States. Principal significant independent variables found were density of population, family income, and ratio of city population to that of the standard metropolitan area in which the city is located. Grouping cities (i.e., core city of major metropolitan area, core city of minor metropolitan area, high-income residential suburb or satellite city, and major resort city) is considered more meaningful than population size when comparing city expenditures. Per capita expenditures in industrial suburbs are higher than in all other groups except major resort cities.

30. Carroll, John J., and Seymour Sacks, "The Property Tax Base and the Pattern of Local Government Expenditures: The Influence of Industry," Regional Science Association Papers and Proceedings, Vol. IX, 1962, pp. 173-190

An examination of the impact of industry on the property tax base in New York cities, towns and villages. The industrial base was found to be related to total per capita operating expenditures for general government, highways, sanitation, police and fire protection.

31. Chapin, F. Stuart, Jr., Urban Land Use Planning, University of Illinois Press, Urbana, Ill., 2nd ed., 1965, 498 pp.

Reviews theories on urban land use, analytical aspects of land use planning. Of particular interest are sections dealing with values and limitations of regional concepts and economic base analyses, methods and techniques of population analysis, and studies relating to land use and cost-revenue surveys.

32. Duncan, Otis Dudley, "Optimum Size of Cities," in Paul K. Hatt and Albert J. Reiss, Jr. (eds.), Cities and Society, The Free Press of Glencoe, Ill., 1951, pp. 632-645

Basic analyses summarizing much empirical evidence on relations between city size and criteria or indexes of environmental quality. The validity of various criteria is examined from the viewpoint of the planner interested in establishing general standards. Compares city sizes and their relationship to the following elements: physical plan of the city, health and public safety, municipal efficiency, education and communications, public recreation, retail facilities, family life, and other psychological and social characteristics of urban life.

33. Dyckman, John W., and Reginald R. Isaacs, with the assistance of Peter R. Senn, Capital Requirements for Urban Development and Renewal, McGraw-Hill Book Company, Inc., New York, 1961, 334 pp.

Exhaustive case study of urban renewal requirements and costs for a selected U.S. city of 300,000 population. Detailed methodology.

34. Hansen, Niles M., "The Structure and Determinants of Local Public Investment Expenditures," The Review of Economics and Statistics, Vol. XLVII, No. 2, May 1965, pp. 150-162

A number of hypotheses on causal factors affecting community investment are developed and tested with empirical evidence from East Flanders, Belgium. Divides public overhead capital into social overhead capital (i.e., public housing, education, health) and economic overhead capital (roads, electric power, water, sewer systems), analyzing the relation of each to population size and density, community growth, and other variables .

35. Harris, Britton, "Some Problems in the Theory of Intra-Urban Location," Operations Research, September-October 1961, pp. 695-721

A basic examination and development of locational equilibrium models relevant to problems of urban form and patterns of metropolitan development. Includes a brief discussion of the outlines of the Penn Jersey Transportation Study model. "It is concluded that existing theories of urban form are largely descriptive and taxonomic, while existing theories of locational behavior may be inadequate to deal with the inflexibilities and nonlinearities that arise in the urban framework."

36. Hirsch, Werner Z., "Expenditure Implications of Metropolitan Growth and Consolidation," The Review of Economics and Statistics, Vol. XLI, No. 3, pp. 232-241

Develops and empirically tests a theoretical framework for analyzing effects of metropolitan growth. Concludes that locational, efficiency, and institutional considerations will cause services to be rendered in three different ways: 1) horizontally integrated service plants (education, fire and police protection); 2) circularly integrated plants (central administration of government); and 3) vertically integrated plants (water and sewerage). Only the latter will produce declining per capita expenditures up to a large scale.

37. _____, "Local Versus Areawide Urban Government Services," National Tax Journal, Vol. XVII, No. 2, December 1964, pp. 331-339

Discussion of criteria determining whether a certain service is best performed on a local or areawide basis. Major economies of scale exist in air pollution control, sewage disposal, public transportation, power, water, public health services, hospitals, and planning. Suggests city size of 50,000 to 100,000 with no more than 250,000.

38. International Urban Research, The World's Metropolitan Areas, University of California Press, Berkeley and Los Angeles, 1959, 115 pp.

This monograph attempts to establish greater international comparability in the delimitation of urban populations. Provides a classification by country and continent of the world's metropolitan areas of more than 100,000 inhabitants and gives a brief analysis of the problems of delimiting urban boundaries.

39. Isard, Walter, and Robert E. Coughlin, Municipal Costs and Revenues Resulting from Community Growth, Chandler-Davis Publishing Company, Wellesley, Mass., 1957, 111 pp.

Still the principal study of costs of urban facilities in the United States. Contains a detailed methodology for calculating costs and revenues for residential or residential-industrial additions to a city, based on density, income level, size of industrial and commercial districts, level of services to be provided, and industry mix. Revenues from increments to property taxes at various rates are calculated and compared with costs.

40. Jones, Robert, "Transport and Urban Design: Some Trade-Offs Related to Housing," in Edwin T. Haefele (ed.), Relating Transport to National Policy, The Brookings Institution, Washington, D.C., 1968

Detailed comparison of costs of low- and high-density residential patterns for a hypothetical new city. Trade-offs between building costs and costs of transportation and utilities are shown for alternative schematic layouts, for 1-story and 4-story construction. Unit cost data are drawn primarily from Ciudad Guayana, Venezuela. Calculations are presented separately for intraneighborhood and city-wide costs. Concludes that least total cost for the alternatives studied results for 1-story dwellings at a density of 22 units per gross acre, as compared to 4-story apartments at 71 dwelling units per gross acre.

41. Kain, John F., "Urban Form and the Costs of Urban Services," Program on Regional and Urban Economics, Discussion Paper Number 6, Harvard University, May 1967, 108 pp.

Review of major studies on the effect of residential density on costs and urban development. "Development standards appear to be more important than differences in residential density or urban form in determining outlays for urban services."

42. Ludlow, William H., "Costs of Public Services in Various Urban Patterns and Densities," in Coleman Woodbury (ed.), Urban Development: Problems and Practices, University of Chicago Press, Chicago, Ill., 1953, pp. 140-167

An early study on governmental costs for a single residential area, residential areas in different sections of the city, and overall city areas, including commercial and industrial areas. Tables give costs of public services in various urban patterns and densities

and by population size groups. School, health, library, and some recreational service costs are found to be roughly proportional to the population served regardless of density. The cost of streets, utilities, refuse disposal and parks varies considerably with the density of development. Fire protection and some police costs depend partly on the character of the population, density of development, and type, design, and construction of property served.

43. Mace, Ruth Lowens, Costing Urban Development and Redevelopment, Institute of Government, University of North Carolina, Chapel Hill, July 1963

A revised, enlarged, and updated version of an earlier bibliography on costs of providing municipal services. Traces the history of cost-revenue analysis in city planning and urban renewal.

44. McCallum, David Livingston, A Case Study of the Cost of Governmental Activities in Single-Family Residential Areas of Different Density, Ph.D. thesis, University of North Carolina, Department of City and Regional Planning, Chapel Hill, 1956, mimeo

Develops a method of analyzing the relationship between residential densities and the cost of carrying on the activities of a government unit in urban residential areas. Applies to a tract of land for several densities and degrees of development in the Greensboro, N.C., metropolitan area.

45. McHugh, F. Dodd, "Cost of Public Services in Residential Areas," American Society of Civil Engineers Transactions, Paper No. 2163, Vol. CVII, 1942, pp. 1401-1446

A pioneering study on city expenditures for permanent improvements and public services in old, as compared with new, residential areas. Although dated, and limited to the conditions in New York City, the study contains very useful standard and cost data and helpful guidelines with respect to methodology of such an analysis for other cities.

46. Montgomery, Albert E., Washington Municipal Expenditures, 1941-1957: An Economic Analysis, Washington State University, Bureau of Economic and Business Research, Bulletin No. 38, Pullman, Wash., March 1963, 157 pp.

Analyzes expenditure patterns of Washington state municipalities for general government, street lights, streets, police, fire, health, and recreation. Total per capita spending for these functions is correlated with community size and population density but varies by function. Higher spending per capita in larger cities is mainly attributable to fire and recreation and, to a lesser extent, police expenditure. Per capita water, sewer, and general government expenditures, however, show a tendency to decrease. Municipal operations are not comparable as among large, medium, and small cities, due to variety and nature of services and facilities. Per capita

assessed valuation, which tends to increase with city size, is a dominant factor, affecting the character and scope of a city's service responsibilities.

47. Parr, Percy, "Local Government Reform: An Engineer's Comments," Journal of the Institution of Municipal and County Engineers, London, August 7, 1945, pp. 20-37

The author averaged costs and rates for highways, education, police, health, refuse, and sewage for towns with various populations in the county boroughs of England and Wales. The highest rates of expenditure are in the biggest towns and the lowest total gross rate per head corresponds to a town of 110,000.

48. Schaller, Howard G. (ed.), Public Expenditure Decisions in the Urban Community, Resources for the Future, Inc., Washington, D.C., 1963, 198 pp.

Papers presented at a conference, May 14-15, 1962. Papers of particular interest to an analysis of urban costs include: Werner Z. Hirsch, "Quality of Government Services;" Allen D. Manvel, "Changing Patterns of Local Urban Expenditure;" and Seymour Sacks, "Spatial and Locational Aspects of Local Government Expenditures."

49. Schmandt, Henry J., and G. Ross Stephens, "Measuring Municipal Output," National Tax Journal, Vol. XIII, No. 4, December 1960, pp. 369-375

Develops an index for rating the output of municipal services, based on the number of municipal subfunctions or activities performed. Inclusion of the service index in a statistical analysis of expenditures for some 19 local areas in Wisconsin suggests existence of economies of scale in general government functions, police protection, and school district operations.

50. Scott, Stanley, and Edward L. Feder, Factors Associated with Variations in Municipal Expenditure Levels--A Statistical Study of California Cities, University of California, Berkeley, Bureau of Public Administration, February 1957

A study of 195 selected California cities of over 2,500 population and of 12 measurable characteristics of the cities. Most of the variations in per capita municipal expenditures were associated with variations in per capita property value and the retail sales index.

51. Shapiro, Harvey, "Economies of Scale and Local Government Finance," Land Economics, Vol. XXXIX, No. 2, May 1963, pp. 175-186

Analysis of per capita expenditures and revenues by city size groups, utilizing Census data. Supports thesis that economic efficiency may be greatest in medium-sized communities of roughly 50,000-100,000.

52. Shapiro, Harvey, "Measuring Local Government Output: A Comment," National Tax Journal, Vol. 14, No. 4, December 1961, pp. 394-397

Application of Schmandt-Stephens municipal output index to 66 Wisconsin counties.

53. Stone, P. A., Housing, Town Development, Land and Costs, The Estates Gazette Limited, London, 1963, 154 pp.

An analysis of the cost consequences of alternative housing solutions, comparing the costs of high density housing in the center of existing towns against low density development in suburbs, in extended and in new towns. Costs of different types of town development and patterns for shopping, schools, industry, public buildings, and open space are analyzed. The impact of different costs on various types of developers, users, and the community is explained.

54. U.S. Advisory Commission on Intergovernmental Relations, Intergovernmental Policies for Urbanization and New Community Development, 1968, 190 pp. (draft)

Traces U.S. pattern of urbanization, causes and effects of regional, state, and local population and economic growth. See also by the same commission, Performance of Urban Functions: Local and Areawide, Report M-21, September 1963, 281 pp. and Metropolitan Social and Economic Disparities: Implications for Intergovernmental Relations in Central Cities and Suburbs, January 1965, 253 pp.

55. U.S. Housing and Home Finance Agency, The Cost of Municipal Services in Residential Areas, A study prepared by the Department of Regional Planning, Harvard University, by William L. C. Wheaton and Morton J. Schussheim, PB 111652, U.S. Dept. of Commerce, Office of Technical Services, Washington, D.C., 1955, 105 pp.

A very useful guide for urban development planners in measuring long-term costs of municipal services in different types of areas. Three representative suburban communities were analyzed to show costs of additional residential growth of 500 or 1,000 houses in two or more locations and at several densities. Principal variables affecting costs include age and degree of utilization of existing facilities, location and density of new residential development (50 percent or more variation in capital outlays), composition of the population, and service levels (as much as 50 percent variation in capital outlays and 25 percent for annual operating expenses). An appendix contains details of the technical procedures used, which can be adapted for similar analyses in developing countries.

56. Warren, Robert, "A Municipal Services Market Model of Metropolitan Organization," Journal of the American Institute of Planners, Vol. XXX, No. 3, August 1964, pp. 193-204

Particularly helpful but brief analysis of economies of scale, noting: ". . . a small municipality can realize economies of scale by separating production from control over the provision of services

and utilizing external producers" and that "there is little data to suggest that a single set of boundaries will be optimal for all services in terms of economic criteria."

57. Webber, Melvin M., et al., Explorations into Urban Structure, University of Pennsylvania Press, Philadelphia, Penn., 1964, 246 pp.

Conceptual probes into basic issues of urban growth and planning.

58. Wingo, Lowdon, Jr., Transportation and Urban Land, Resources for the Future, Inc., Washington, D.C., 1961, 132 pp.

A framework for analyzing and projecting urban organization. A model is developed which identifies the amount, distribution, and value of land required for residential uses.

III. Costs of Individual Facilities and Services

Roads

59. Betz, Mathew J., "Highway Maintenance Costs - A Consideration for Developing Areas," Highway Research Board, Highway Research Record No. 94, Washington, D.C., 1965, pp. 1-27

Reports analysis of available U.S. and international data on maintenance as compared to construction costs for dirt, gravel, bituminous surface-treated, mixed bituminous, and portland cement concrete roads.

60. De Weille, Jan, Quantification of Road User Savings, International Bank for Reconstruction and Development, Washington, D.C., 1966, 93 pp.

Methodology and data for analyzing road user savings resulting from improvement in road quality.

61. Highway Research Board, Highway Capacity Manual 1965, Special Report No. 87, Washington, D.C., 1965, 397 pp.

Basic highway engineering reference handbook. Practical guide permitting determination of the capacity, service volume, or level of service which will be provided by either a new highway design or an existing highway, under specified conditions. Alternately, given a certain traffic demand, the design necessary to accommodate that demand at a given level of service can be determined.

62. Lago, Armando M., Intercity Highway Transportation Cost Functions in Underdeveloped Countries, Ph.D. dissertation, Harvard University, September 1966, 265 pp.

Fundamental analysis of optimum technology in intercity highway transportation. Largely outside the scope of the urban infrastructure study, but noteworthy of citation because of analytical depth on cost problems.

63. Moyer, R. A., and J. E. Lampe, "Study of Annual Costs of Flexible and Rigid Pavements for State Highways in California," in Highway Research Board, Highway Research Record No. 77, Publication No. 1262, 1965, pp. 133-172

Gives results for more than 600 solutions of costs of pavements in which effect on annual cost of eight major variables is set forth. Included in the variables are interest rates of 3 and 6 percent, service life of initial pavement, and average maintenance costs.

64. Oglesby, C. H., and M. J. Altenhofen, The Economics of Design Standards for Low-Volume Rural Roads, EEP No. 26, Stanford University, Dept. of Civil Engineering, July 1967, 308 pp.

Explores the costs and benefits to highway agencies and highway users through a range of design standards for low-volume rural roads. Primary attention is focused on standards for roadbed width and six surface types. Construction, maintenance, vehicle-operating and time costs are derived for the various cross sections and are brought together at 7 percent interest to give annual cost comparisons between the alternative standards.

65. Soberman, Richard M., Transport Technology for Developing Regions: A Study of Road Transportation in Venezuela, The M.I.T. Press, Cambridge, Mass., 1966, 177 pp.

As a case study in technological choice, a detailed analysis is presented in Chapter 3 on the interaction of road design standards with costs of construction, pavement, maintenance, and vehicle operation. Labor, local capital, and foreign exchange components are estimated separately to permit analysis of substitutability.

66. Stanford Research Institute, A Manual for Conducting Highway Economy Studies, by David A. Curry and Dan G. Haney, Menlo Park, Calif., August 1966, 163 pp.

This manual contains detailed instructions and worksheets for computing various indexes to measure the economic desirability of highway improvement projects, and for selecting an optimal set of projects to be included in a budget planning period.

67. Steel, Robert, "Town Development - Roads and Economics," The Journal of the Institution of Highway Engineers, Vol. 12, September 1965, pp. 16-30

Describes alternative road layouts proposed in town development plan of Basingstoke, U.K., for projected population expansion from 26,000 (1961) to 76,000 (1976). The focus is on ring, spine, and distributor roads to serve in transformation of the urban center, promoting growth while protecting urban land values.

Water and Sewerage

68. Babbitt, Harold E., Sewerage and Sewage Treatment, 6th ed., John Wiley & Sons, Inc., New York, 1949, 692 pp.

A basic textbook covering all aspects of sewerage and sewage treatment, of value to the urban planner interested in a number of infrastructure problems. Emphasizes difficulty of obtaining reliable cost data, even in the United States, due to differences in design and local conditions. Discusses the increasing problem of industrial waste loads and factors involved in its solution, variables affecting costs of sewage treatment processes, and sewer maintenance costs.

69. Dieterich, Bernd H., and John M. Henderson, Urban Water Supply Conditions and Needs in Seventy-Five Developing Countries, Public Health Paper No. 23, World Health Organization, Geneva, 1963

An analysis of existing urban water supply conditions, deficiencies, present and future needs, and costs and means of financing in 75 developing countries. Estimates that less than 33 percent of urban houses are supplied with piped water, usually on an intermittent basis with no quality control. Construction of urban waterworks in almost all the countries does not keep pace with present or future needs, and there is a real potential danger to urban health and economic development.

70. General Electric Company, Water Treatment Processes for Rural Communities in Developing Countries, prepared for Agency for International Development as one of a series on Generation and Utilization of Power in Rural Areas of Developing Countries in collaboration with the Center for International Studies, M.I.T., Stanford Research Institute, and CARE, Inc., December 1962, 43 pp.

Main objective of this study is a review and evaluation of water treatment methods and available equipment capable of providing potable water at costs compatible with economic conditions in underdeveloped areas of the world. Concludes there is no single best method--each situation must be evaluated. Standards of water quality vary enormously, as do cost factors. Presents rough cost estimates based on desirable maximum costs and field conditions.

71. India, Government of, Calcutta Metropolitan Planning Organisation, Survey of Water Supply Resources of Greater Calcutta, Master Plan for Water Supply, Sewerage and Drainage, Calcutta Metropolitan District (1966-2001), report prepared for the World Health Organization acting as Executing Agency for the United Nations Development Programme (Engineering Consortium: Metcalf & Eddy Limited, Boston, Mass., and Engineering-Science Inc., Arcadia, Calif.), December 1966

Major planning document. Includes immediate action proposal for safe drinking water supply and sanitation as initial measures in urban improvement program.

72. Kuiper, Edward, Water Resources Development: Planning, Engineering, and Economics, Butterworth & Co., Ltd., London, 1967, 483 pp.

Comprehensive reference. Includes chapters on municipal water supply and on cost and benefit analysis.

73. New York State, Office of Local Government, Study of Needs for Sewage Works, A New Ten-Year Program for Aiding Municipalities, Report No. 1, Albany, N.Y., February 1962, 90 pp.

Report of a major statewide study of water quality and pollution control. The extent of adequate and inadequate sewage treatment is estimated for each county, classified by degree of urbanization. Data are separately combined for each major receiving water course. Costs of needed sewer systems and treatment plants are estimated for each county, and for illustrative combined systems. Recommendations on legislation and new policies with respect to state aid and local powers, including municipal debt incurring powers, are presented. Appendixes include engineering cost curves for sewage treatment plants, sanitary sewer systems, sewers and force mains, sewage pumping stations, and operation and maintenance of sewage treatment plants.

74. United Nations, Department of Economic and Social Affairs, Water for Industrial Use, New York, 1958, 44 pp.

The report contains a brief review of problems which arise from the demand for water by industry in competition with older and more traditional claims on water resources, quantity and quality aspects of industrial water use, industrial water costs, possible means open to industrial plants and public authorities of conserving limited water resources, and conclusions and suggested actions to be taken at national and international levels.

75. U.S. Department of Health, Education, and Welfare, Public Health Service, Modern Sewage Treatment Plants - How Much Do They Cost? - A Practical Guide to Estimating Municipal Sewage Treatment Plant Construction Costs, PHS Publication No. 1229, Washington, D.C., 1964, 37 pp.

Study based on a tabulation of design and actual cost information for 1,504 sewage treatment projects built with PHS grants between 1956 and 1963.

Electric Power

76. Hofmeister, Ralph H., Cost Analysis of Electricity Supply Systems for Rural Communities, prepared for Agency for International Development by Center for International Studies, M.I.T., as one of a series (see reference 70), March 1963, 165 pp.

A cost analysis of alternative means of rural energy supply in underdeveloped regions. Costs are stated in terms of operational variables and parameters so that differing prices, demand conditions, and

design variables may be introduced. Total costs for each component are given in terms of indivisible costs, marginal costs per unit of capacity, and marginal costs per unit of energy. Concludes that a grid supply is best for rural areas, as grid extensions are cheaper than local generation even with low initial demand. Diesel plants compare unfavorably except in very isolated areas.

77. Nerlove, Marc, Estimation and Identification of Cobb-Douglas Production Functions, Rand McNally & Company, Chicago, Ill., 1965, 193 pp.

Statistical analysis of production and cost functions. Estimates economies of scale at the enterprise level in U.S. steam electricity generation, showing a marked degree of increasing returns to scale but at a diminishing rate with increasing output.

78. United Nations Economic Commission for Asia and the Far East, Electric Power in Asia and the Far East 1964, New York, 1966, 106 pp.

Compilation of statistics on power supply and distribution systems in ECAFE region. Contains tables on costs of recently constructed generating, transformer, transmission, and distribution systems, but without detailed cost breakdowns.

79. _____, Public Electricity Supply--A Manual on Management, New York, 1965, 100 pp.

Detailed manual on administration of an electricity supply system. Includes chapter on cost calculation and rate-making.

80. United Nations Economic Commission for Europe, Economic Methods and Criteria Used in the Selection of Investments in the Electric Power Industry, ST/ECE/EP/21, Geneva, 1963, 64 pp.

A preliminary study of the fields in which useful comparisons could be made between the economic methods and criteria used in different countries in arriving at a number of solutions to problems encountered in the construction and operation of electric power plants and in the transmission of the electric power produced. A sophisticated study utilizing linear programming method supplemented by marginal coefficients.

81. U.S. Federal Power Commission, Hydroelectric Power Evaluation, July 1968

A technical memorandum for the use of the Bureau of Power to facilitate the making of estimates of electric power costs and values as required in the work of the Bureau, to assure uniformity in the making of such estimates, and to standardize procedures. Particularly helpful in a study of urban costs is the section on Transmission Costs, covering the facilities of the connecting transmission lines, the step-down or receiving substation at the market terminal, and intermediate switching stations. Data are for the United States but can be used for comparison with cost data of other countries.

82. Westinghouse Electric Corporation, Electrical Transmission and Distribution Reference Book, 4th ed., East Pittsburgh, Penn., 1950, 824 pp.

Practical reference book on electric power transmission systems authored by the Central Station Engineering Group of the Westinghouse Electric Corporation.

Housing

83. Burns, Leland S., Cost-Benefit Analysis of Improved Housing, a case study prepared as part of the International Housing Productivity Study, University of California, Los Angeles, mimeo. See also United Nations Research Institute for Social Development, Cost-Benefit Analysis of Social Projects, Report No. 7, Geneva, April 1966, 129 pp.

Case study of benefits of community housing project.

84. Frankenhoff, C. A., "Elements of an Economic Model for Slums in a Developing Economy," Economic Development and Cultural Change, Vol. 16, No. 1, October 1967, pp. 27-36

Presents an approach for advancing the integration of slums in developing countries with the functions of the urban centers of which they are a part.

85. Great Britain Ministry of Housing and Local Government, Housing Standards, Costs and Subsidies, British Information Services, Circular No. 36/67, HMSO, London, April 25, 1967, 31 pp.

Statement of policy and procedures governing loans and subsidies on housing schemes which meet Parker Morris committee standards. Comprehensive cost yardstick is established, based on number of persons per dwelling and per acre.

86. Stone, P. A., Housing, Town Development, Land and Costs, The Estates Gazette Limited, London, 1963, 154 pp.

Elaboration and extension of cost analyses described in reference 87.

87. _____, "The Economics of Housing and Urban Development," Journal of the Royal Statistical Society, Series A (General), Part IV, 1959, pp. 417-483

A pioneering examination of alternative cost policies in urban development in England. It explores techniques of costing for different types of housing developments for houses and flatted blocks of various heights, for estates at various densities, and for constructing neighborhoods, town extensions, and new towns. Estimates are given of the costs of living and operating in towns of different sizes. Development costs (i.e., roads, sewers) are shown to be about 50 percent higher in central areas than in peripheral areas. The largest

single element of costs in the town is housing, including development--about 55 percent of total costs. Small provincial towns appear to have lower real costs as a location for urban development than the larger and older urban centers, due partly to lower environment costs, lower prices, and advantage of virgin sites over previously developed sites. The new town is more expensive.

88. Turner, John C., "Barriers and Channels for Housing Development in Modernizing Countries," Journal of the American Institute of Planners, Vol. XXXIII, No. 2, May 1967, pp. 167-181

Advocates "progressive development," as opposed to "instant" development with the modern minimum standards prescribed by authorities. A case study of squatter settlements near Lima shows 'the squatter's procedure of occupying his plot as soon as he obtains possession, living initially in any sort of shelter he can manage, allows his family to improve its living conditions and to become far more independent at a much earlier and a more active stage of life." The argument that progressive development (which demands one-family housing) is uneconomic because of the immense areas required and the increase in spread and costs of urban services collapses on close examination. In Lima the demand and need were very low in the initial stages. "The average lower income family seeking a home in an urban environment wants secure land tenure, community facilities, an adequate dwelling, and utilities in that order."

89. United Nations Economic and Social Council, Committee on Housing, Building, and Planning, Finance for Housing and Community Facilities in Developing Countries, E/C.6/32/Rev. 1, New York, 1965, 175 pp.

One of the few studies estimating costs of selected infrastructural items in developing countries. Analyzes the number of units, capital requirements, and related financial implications of a program that would meet the demands of certain sectors of urban development in developing countries. Concludes that such a program at current costs would require total capital of more than 8 percent of aggregate national income, but that the cost of a program that would be 80 percent satisfactory would be less than half that of meeting the deficit, based on current wages and costs. If costs for new middle- and lower-cost housing are reduced, housing and related facilities for 80 percent of the urban population could be supplied at an estimated 3.6 percent of aggregate national income. Contains a methodology for cost estimates when data are limited.

90. _____, Committee on Housing, Building, and Planning, Goals and Standards for Housing and Environmental Development, E/C.6/62, Geneva, January 15, 1964, 19 pp.

Reviews targets set for "United Nations Development Decade": total construction and ancillary facilities of from 19 to 24 million units annually during latter half of the 1960s. Using low cost construction techniques, cost per house in <u>urban areas</u> could be reduced to

$500 and necessary ancillary services to $500 ($200 for each in rural areas). Stresses need for development of efficient building materials and construction industries. Examples of housing standards set by various countries are given: Ceylon - one house per 4.84 persons (average family size), 2 rooms, floor area about 500 square feet. Considered "desirable" (better than minimum): area of 35 to 80 square feet per person, water in house, private sanitary waste disposal, adequate drainage, domestic electricity.

91. United Nations Economic Commission for Europe, Effect of Repetition on Building Operations and Processes on Site, ST/ECE/HOU/14, New York, 1965, 139 pp.

The purpose of this report is to establish the influence on labor productivity and building costs of the scale of production and the degree of repetition of operations carried out on the building site. Scope was restricted to the effect of repetition on operational times and on the cost and productivity of building operations on site, and organizational problems.

92. Van Huyck, A. P., and K. C. Rosser, "An Environmental Approach to Low-Income Housing," International Development Review, Vol. VIII, No. 3, September 1966, pp. 15-18

Lacking massive resources to rehouse Calcutta's 700,000 bustee residents, the Calcutta Metropolitan Planning Organization has sponsored legislation for a massive environmental improvement program, to cover over 500,000 persons in five years at an estimated public works cost of Rs. 187 ($25) per capita. As minimum tolerable standards the program includes: a safe water system, with one water point per 33 persons and communal baths at the scale of two per 100 persons; a sanitary sewerage system, with one sanitary latrine seat per 25 persons; a storm drainage system; paving of streets and lanes; electric light connections to lanes and huts; and filling of insanitary ponds. A community development program based heavily on voluntary leadership and organization is being launched to promote proper use and maintenance of the physical improvements.

Education

93. Anderson, C. Arnold, and Mary Jean Bowman (eds.), Education and Economic Development, Aldine Publishing Co., Chicago, Ill., 1965, 436 pp.

Outgrowth of a conference on The Role of Education in the Early Stages of Development, held in Chicago in 1963, this volume presents an interdisciplinary approach by historians, economists, educators, and geographers to the analysis of relationships between education and economic development. Includes several chapters of interest to the study of urban infrastructure, but only one writer, Arnold C. Harberger, attempts to analyze actual costs of various types of education.

94. Hanson, Nels W., "Economy of Scale as a Cost Factor in Financing Public Schools," National Tax Journal, Vol. XVII, No. 2, March 1964, pp. 92-95

Based on the author's Ph.D. dissertation, this article identifies and describes the relationship between the size of a school district as measured by average daily attendance and its expenditures per pupil for current costs of public education. The algebraic analysis showed evidence of economies of scale through a large part of the size continuum and diseconomies of scale when district size exceeds the optimum. The optimum district size in terms of per pupil costs was found to be above 20,000 average daily attendance in all states, and the median for the optimum was 50,000. For an analysis of educational performance in relation to district size and expenditures, see reference 99.

95. Harbison, Frederick, and Charles A. Myers, Manpower and Education: Country Studies in Economic Development, McGraw-Hill Book Company, New York, 1965, 343 pp.

Following on the authors' study of Education, Manpower, and Economic Growth, this is a more detailed analysis of a number of developing countries, written by associates. Makes important recommendations with regard to educational programs in these countries. Although the essays touch very little on cost factors, they do provide valuable guides to planners of urban infrastructure with respect to strategies, pitfalls, and experiences in a number of countries. Emphasizes the difficulty of deciding how much reliance to place on pre-employment formal training as opposed to on-the-job training. Several essays conclude that investments in vocational schools at the secondary level bring poor returns.

96. Hirsch, Werner Z., "Determinants of Public Education Expenditures," National Tax Journal, Vol. XIII, No. 2, March 1960, pp. 29-40

Model developed using population size and sociological, physical, economic, and government characteristics, and adding scope and quality of education. Tested for the St. Louis area. "A district's financial ability to afford education measured in terms of per pupil assessed valuation of real property was by far the single most significant determinant . . . But perhaps the most important factor is the absence of significant economies of scale in the school districts. . . ."

97. Hirsch, Werner Z., and Elbert W. Segelhorst, "Incremental Income Benefits of Public Education," The Review of Economics and Statistics, Vol. XLVII, No. 4, November 1965, pp. 392-399

This case study used multivariate analyses to test the magnitude of the relationship between the level of education and income when differences due to other factors were taken into account. Eleven variables, based on 1957 St. Louis area data, were used; those, besides education, found to have a significant influence on income were sex, race, occupation, and self-employment and supervisory status.

98. India, Ministry of Education, Report of the Education Commission 1964-66 - Education and National Development, New Delhi, 1966, 692 pp.

Summary of recommendations by the Education Commission on the national pattern of education and on general principles and policies for development of education at all stages and in all aspects. Divided into three parts: general problems, different stages and sectors of education, and problems of implementation.

99. Kiesling, Herbert J., "Measuring a Local Government Service: A Study of School Districts in New York State," The Review of Economics and Statistics, Vol. XLIX, No. 3, August 1967, pp. 356-367

Analyzes pupil achievement scores in relation to per pupil expenditure and school district size, attempting to isolate the influences of pupil intelligence and socioeconomic background. "The findings have been somewhat surprising. Size of school district is negatively related to performance, if at all, and expenditure is related strongly to performance only in larger school districts." On the basis of the generally weak relationship of performance to expenditure, points out the danger of attempting to use per capita cost figures as a measure or index of the quality of public services.

100. U.S. Department of Health, Education, and Welfare, Office of Education, Problems in Planning Urban School Facilities, OE-21023, Bulletin 1964, No. 23, by William W. Chase, 1964, 63 pp.

Problems reported by school officials interviewed in 50 cities on construction costs. They found difficulty in making valid cost comparisons and in relating construction costs to educational efficiency. "Cost units are difficult if not impossible to compare unless compensations are made for cost trends, regional differentials, types of educational programs planned and the types of buildings and materials used."

101. Vaizey, John, and J. D. Chesswas, The Costing of Educational Plans, UNESCO, International Institute for Educational Planning, Paris, 1967, 63 pp.

Includes details of classroom types, size, and costs for secondary schools in Africa, as well as teacher costs.

Health and Hospitals

102. Abel-Smith, Brian, Paying for Health Services: A Study of the Costs and Sources of Finance in Six Countries, Public Health Paper No. 17, World Health Organization, Geneva, 1963, 86 pp.

Defines and classifies health costs for cross-national studies. Reports on a pilot study in which these definitions were applied in six different countries with varying systems of financing health services and different standards of living. Results showed both striking

similarities and differences in the role played by health services in the national economy. Concludes that this system of classification could be used by a country in its routine statistics, to study trends in health expenditures, and also for cross-national comparisons.

103. Cohen, Harold A., "Variations in Cost among Hospitals of Different Sizes," The Southern Economic Journal, Vol. XXXIII, No. 3, January 1967, pp. 355-366

Analyzes hospital operating costs through two adjustments: correcting for wage differentials between larger, urban hospitals and those in smaller communities; and measuring output by application of a weighting system to the services performed by different hospitals. Measuring cost per service unit, concludes from the regression analysis that a quadratic relationship is most economically meaningful, giving a "slowly rising straight line marginal cost curve and a 'U' shaped average cost curve. The average cost curve has a low point between 80-85,000 units of service or about 160-170 beds. The low point of this average cost curve is approximately $21.25. Average cost is below $21.35 for the range from 60,000-115,000 or from about 125-235 beds. This is a smaller hospital than previously appeared to be least cost but most of the range is well above the national median size of hospitals." Costs as studied do not include depreciation.

104. Llewelyn-Davies, R., and H.M.C. Macaulay, Hospital Planning and Administration, Monograph No. 54, World Health Organization, Geneva, 215 pp.

General plans for all countries for a health service, medium sized general hospital, and individual services and departments.

105. Pennsylvania Commonwealth, Report of the Hospital Cost and Utilization Committee, by the Governor's Hospital Study Commission, Harrisburg, Penn., April 30, 1966, 66 pp.

Study of 172 short term general hospitals by the Pennsylvania Economy League, Inc., on variations in hospital costs, departmental costs, and control of hospital costs.

106. World Health Organization, Environmental Health Aspects of Metropolitan Planning and Development, Technical Report Series No. 297, Geneva, 1965, 66 pp.

All features of the urban environment, not narrowly confined to health, are reviewed in this report by an expert international committee. Difficulty of reaching clearly defined criteria or standards for environmental health is made evident.

IV. Industrial Location and Infrastructure Requirements

107. Borchert, J. R., Belt Line Commercial-Industrial Development: A Case Study in the Minneapolis-St. Paul Metropolitan Area, University of Minnesota, Depts. of Agricultural Economics and Geography, Minneapolis, November 1960, 87 pp.

Surveys adjustments in land use consequent on development of a major arterial highway and projects future developments in relation to new interstate highway. Advocates early land acquisition for highway development to permit rational land use planning and adjustments.

108. Creamer, Daniel, assisted by Richard Rothman, Changing Location of Manufacturing Employment, Part I, Changes by Type of Location, 1947-1961, National Industrial Conference Board, Studies in Business Economics, No. 83, New York, 1963, 152 pp.

Analyzes shifts in manufacturing employment by type of community. Principal trend is one of "primary diffusion" from central cities to their peripheral areas.

109. Duncan, Otis Dudley, et al., Metropolis and Region, published for Resources for the Future by The Johns Hopkins Press, Baltimore, Md., 1960

This study provides cross-sectional views of the metropolis in the United States at the middle of the 20th century. Analyzes data on the industrial structure of about 50 SMAs (standard metropolitan areas), seeking to provide a picture of the functional differentiation of large cities and their economic links with hinterland areas. Trade links between a metropolitan area and its hinterland were found to be less important than its links to other metropolitan areas.

110. Dunning, J. H., "Manufacturing Industry in the New Towns," Manchester School of Economic and Social Studies, May 1960, pp. 137-150

An examination of the industrial structure of 10 new towns in Great Britain in 1957-58, when 62 percent of the total labor force in the new towns was engaged in manufacturing (national average--40 percent). The structure of manufacturing industry consisted of a concentration within engineering, 49.1 percent (national average--20.4 percent); with another 27.7 percent employed in scientific and photographic instruments, motor vehicles, and "other manufacturing industries." Those industries with below national average percentages were textiles, metal manufacturing, chemicals and food, drink, and tobacco trades.

111. Eddison, John C., "Industrial Growth and Urban Land Requirements in East Pakistan," The Pakistan Development Review, Vol. III, No. 4, Karachi, Winter 1963, pp. 548-565

A pioneering study relating industrial expansion to land requirements. Scarcity of suitable land for factories is an aspect of the larger problem of inadequacy of urban land for commercial, residential, public utility, and other uses in areas of economic growth. Most expansion is taking place in a few large cities where land is not available. The author estimates the land required under the Third Plan industrialization program, discusses feasible "secondary industrial centers," the disadvantages of "ribbon development," and the need for better coordination between private and public land-improvement efforts.

112. Eddison, John C., "Industrial Location and Physical Planning in Pakistan," The Pakistan Development Review, Vol. I, No. 1, Karachi, Summer 1961

The author was one of the first to analyze in a real setting the general relationships between industrial location programs and major infrastructural facilities. Suggests that governments plan and develop secondary and tertiary regional industrial centers in appropriate locations to counteract tendency to concentrate in a few large urban areas, particularly in developing countries. Centers would combine benefits of industrialization and cost advantages of urban operations. Shows aspects of public expenditures that promote centralization rather than decentralization.

113. India, Town and Country Planning Organisation, Ministry of Health, Coordination of Industrial Development and Location with Urban and Regional Planning and Development, background paper prepared for discussion, mimeo

Comprehensive and penetrating discussion of the practical aspects of integrated industrial development, location, and urban and regional planning. Points out specific problems and suggests remedies. Shows how processes of economic development, industrialization, and urbanization are interwoven, tracing statistically the effects of industrial location patterns on commerce, transport, construction, and services. Makes recommendations regarding control of industrial locations.

114. Israel, Ministry of Commerce and Industry, Programme for Israel's Industrial Development: Second Outlook, 1965-1970, Hatchiya Printing Press, Israel, no date

A comprehensive plan for industrial development, of great value to general industrial development planners. National policy emphasizes the dispersal of population by such means as setting up industrial plants in towns, townships, and regional settlement centers.

115. Kádas, Coloman, "The Impact of the Development of Transportation on the Optimal Size of Plant and on Optimal Regional Location," The Regional Science Association Papers, Vol. XII, 1964, pp. 193-201

The effect of transportation on regional economic structure and its application to optimal plant location and plant size.

116. Klaassen, L. H., Methods of Selecting Industries for Depressed Areas: An Introduction to Feasibility Studies, Organization for Economic Cooperation and Development, Paris, 1967, 152 pp.

Second in a series on area redevelopment. Presents alternative methods for identifying likely prospects for local industrialization. Detailed description of author's methodology to define interindustry and interregional relationships, based on input-output. Locational requirements of three U.S. labor-oriented growth industries (glass, optical, and electronic components) are examined.

117. Morrissett, Irving, "The Economic Structure of American Cities," The Regional Science Association Papers and Proceedings, Vol. 4, 1958, pp. 239-256

Elaborates a method used by Gunnar Alexandersson in his study, The Industrial Structure of American Cities (1957), to show how urban economic structures are related to geographical location and city size and to indicate the minimum percentage of total employment one would expect to find in each of the major industries in any city of 10,000 or more. Some generalizations: (1) Small cities are much less diversified than large cities and much more specialized; (2) Cities of the South and West are more diversified and less specialized than cities of the Northeast; and (3) As population increases, diversification increases and specialization decreases.

118. National Planning Association, Capacity Expansion Planning Factors - Manufacturing Industries - A Compilation for 252 Manufacturing Industries of Capital Required for New Plant per Unit of Capacity Showing Time-Phased Equipment and Construction Requirements, prepared for Agency for International Development by Robert M. Waddell, et al., Washington, D.C., April 1966

Presents a set of capacity expansion planning factors for 252 U.S. industry groups in the manufacturing sector, as classified by the NPA. Expenditures for replacement, modernization, and expansion are not differentiated. Develops capital:output and input:capital ratios, the former reflecting industry composites as of 1957 and 1958, and the latter, input requirements for integrated, completely new plants. Provides useful guidelines for industrial feasibility studies and component requirements for developing countries. Suggests procedures by which the U.S. factors may be adapted to local prices and conditions in less industrialized countries.

119. O'Bannon, Norman Dale, The Geographic Association of Manufacturing Industries in Standard Metropolitan Areas in 1950, unpublished Ph.D. dissertation, Tulane University, 1964, 214 pp., mimeo

Analyzes geographical associations between U.S. industries by means of correlation coefficients for employment in 152 Standard Metropolitan Areas. Correlations pertain to pairs among 21 two-digit and 52 three-digit manufacturing industries as defined in the Census of

Population. Association of industries due to technical linkages or resource patterns is distinguished from consumer orientation by comparing industry correlations with a correlation of industry employment and population. The high incidence of correlation revealed suggests the need for more discriminating analysis, based on four-digit industries as defined in the Census of Manufactures.

120. Pred, Allan, "Industrialization, Initial Advantage, and American Metropolitan Growth," The Geographical Review, Vol. LV, No. 2, April 1965, pp. 158-185

An attempt to explain the connection between industrialization and urbanization. Examines historical theories and background of large U.S. cities. Model of urban-size growth.

121. Stanford Research Institute, Application of Multiple Regression Analysis to the Study of Industry Location, prepared for the U.S. Dept. of Agriculture, Economic Research Service, Economic Development Div., by Robert G. Spiegelman, Menlo Park, Calif., April 1966, 132 pp.

Results of research on development of multiple regression model. Employment data of 53 U.S. manufacturing industries were studied on a geographical grid to determine the significant area variables influencing their area preferences. The method of approach is outlined and specific regressions given.

122. Stefaniak, Norbert J., "Industrial Location within the Urban Area: A Case Study of the Locational Characteristics of 950 Manufacturing Plants in Milwaukee County," University of Wisconsin, School of Commerce, Bureau of Business Research and Service, Wisconsin Commerce Reports, Vol. VI, No. 5, August 1962, 121 pp.

With urban emphasis this case study focuses on locational characteristics and land use patterns of manufacturing firms in Wisconsin. Thirty-seven locational measurements of 950 manufacturing plants are analyzed within a "cost of friction" framework.

123. Thompson, James H., Methods of Plant Site Selection Available to Small Manufacturing Firms, West Virginia University, Bulletin Series 62, No. 3-3, September 1961

A practical guide for small manufacturing firms and urban communities with respect to factors affecting locational decisions and urban attractions. Directed particularly to decisions of plants with less than 500 employees. Of value to communities in developing countries for self-analysis of their urban facilities and services.

124. Winsborough, Hal. H., "Variations in Industrial Composition with City Size," The Regional Science Association Papers and Proceedings, Vol. V, 1959, pp. 121-131

An examination of the extent of urban concentration in different industries. Local market industries were found to be less urbanized than those serving larger markets and processing industries less urbanized than fabricating industries.

V. Policies, Program Measures, and Analytical Techniques

125. Alexander, P. C., Industrial Estates in India, published for the Small Industry Extension Training Institute by the Asia Publishing House, New York, 1963

An authoritative study of the Government of India's industrial estates program by the former Development Commissioner for Small-Scale Industries, Ministry of Commerce and Industry. Main conclusion is that the industrial estate has been more successful in the larger cities. Compares objectives of the Indian program with those of several other countries, stressing the need for an integrated development approach, simple construction styles, and planning by stages. No cost factors are examined.

126. Andrews, Richard B., "Economic Planning for Small Areas: An Analytical System," Land Economics, Vol. XXXIX, No. 2, May 1963, pp. 143-155

Procedure for urban or multidistrict growth projections, based on analysis of dominant local economic activities relative to activities at state, regional, and national levels. Emphasis on techniques for discerning key, dynamic interrelationships, both physical and institutional.

127. Arrow, Kenneth J., "Discounting and Public Investment Criteria," in Allen V. Kneese and Stephen C. Smith (eds.), Water Research, published for Resources for the Future, Inc., by The Johns Hopkins Press, Baltimore, Md., 1966, pp. 13-32

Definitive theoretical treatment of the appropriate discount rate for public investment decisions. Introduces the concept of "natural rate of interest" as a value counterpart of the "natural rate of growth." Points out that the policy maker who is optimizing with respect to a current decision is also in a position to optimize with respect to reinvestment; investment decisions should therefore be made on the basis of the short term rate of interest, appropriately defined. Discusses the divergence of interest rates between private and public capital in imperfect capital markets.

128. Boley, Robert E., Industrial Districts Restudied: An Analysis of Characteristics, Urban Land Institute, Technical Bulletin No. 41, Washington, D.C., 1961

A study of a large number of industrial parks in the United States. Major conclusions relating to location and infrastructure costs are that successful industrial parks are developed in major metropolitan areas where there is a good market, but lack of land and other factors usually result in their being located in suburban areas rather than in central city areas or smaller communities. Smaller community-sponsored parks are most frequently located in cities with populations of 10,000-50,000.

129. Boudeville, J. R., Problems of Regional Economic Planning, Edinburgh University Press, Edinburgh, 1966, 192 pp.

Concise, advanced review of the principal models of regional analysis, including the author's model of propulsive industry influences. Describes French regional planning in its national and international context.

130. Bredo, William, Industrial Estates: Tool for Industrialization, prepared for the International Development Center, M.I.T., by Stanford Research Institute, The Free Press of Glencoe, New York, 1960

The first comprehensive study of industrial estates on a worldwide basis, intended primarily for the use of development planners. Stresses the advantages to small industrialists and to communities of well-planned industrial estates, e.g., better land use and location of industry, alleviation of congestion in large urban cities by fostering decentralization, lower investment in social overhead, better zoning, and more effective urban redevelopment. Reviews planning factors for individual estates based on experience in a number of countries and discusses cost variables.

131. Hamimy, Ibrahim, "Decisions on Industrial Location in the Developing Countries," L'Egypte Contemporaine, Cairo, January 1966, pp. 37-71

Determines main issues involved and criteria which should be used in finding optimum location for industrial plants. Social benefits and costs are examined and the idea promoted of using social return on capital as a basic criterion. UAR is used as an example of a developing country.

132. Indian Institute of Technology, Urban and Industrial Growth of Kanpur Region, report of the International Seminar sponsored by USAID, New Delhi, Directorate of Industries, Kanpur, Uttar Pradesh, and Indian Institute of Technology, Kanpur, 1967, 92 pp.

Summary of a workshop held in January 1967 which highlighted the importance of applying a regional approach to the problems of economic and social development. Findings and recommendations of an interdisciplinary committee whose discussions centered around establishment of a system of comprehensive regional planning are reported.

133. Isard, Walter, Methods of Regional Analysis: An Introduction to Regional Science, The M.I.T. Press, Cambridge, Mass., 1960, 784 pp.

A basic reference book covering the several techniques of regional analysis, with reference by chapter to population projection; migration estimation; regional income estimation and social accounting; interregional flow analysis and balance of payments statements; regional cycle and multiplier analysis; industrial location analysis and related measures; interregional and regional input-output techniques; industrial complex analysis; interregional linear programming; gravity, potential, and spatial interaction models; and channels of synthesis.

134. Lichfield, Nathaniel, "Cost Benefit Analysis in Urban Development - A Case Study: Swanley," The Regional Science Association Papers, Vol. XVI, 1966, pp. 129-153

A methodology of cost-benefit analysis for city and regional planning. A case study is made of Swanley, England.

135. Maass, Arthur, "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions," The Quarterly Journal of Economics, Vol. LXXX, No. 2, May 1966, pp. 208-226

Argues that benefit-cost analysis can be adapted to incorporate other important objectives in addition to economic efficiency. Considers the legislative process capable of weighing trade-offs between the efficiency criterion and other major objectives, such as income redistribution, provided executive agencies take sufficient initiative in analyzing the factual impact of the various criteria when recommending programs to the legislature. Reviews recent legislative record of standards and design criteria in U.S. housing and urban renewal programs, with rent supplement legislation as a case example.

136. Manne, Alan S. (ed.), Investments for Capacity Expansion: Size, Location, and Time-Phasing, The M.I.T. Press, Cambridge, Mass., 1967, 239 pp.

Theory and techniques are developed for analysis of optimal scale, location, and timing of investment. Collaborative case studies are presented for the Indian aluminum, caustic soda, cement, and nitrogenous fertilizer industries. Both the analytical principles and the methodologies demonstrated have important applications in assessing the desirable expansion of urban infrastructure facilities.

137. Mayer, Albert, The Urgent Future: People, Housing, City, Region, McGraw-Hill Book Company, New York, 1967, 184 pp.

The author, an international innovator in community development and environmental design, proposes a view of the country as an architectural whole. Recommends the attraction of population to culturally self-sufficient middle sized cities and the reduction of traffic volume at its source by better integration of living place, work, and recreation.

138. McGovern, P. D., "Industrial Dispersal," Planning, Vol. XXXI, No. 485, February 1965, 39 pp.

Discussion of problems of concentration and dispersal in relation to the large cities and the regions of the U.K. Examines motivations and experiences of those firms that have recently located plants in Northern Ireland, parallels being drawn with other regions of the U.K. Suggestions are made for a more comprehensive and more clearly organized dispersal policy.

139. Nicaragua, National Urban Planning Office, Ministry of Development and Public Works, Planning of Land and Physical Facilities for Industry and the Establishment of an Industrial Park, Managua, Nicaraguan-American Technical Cooperation Organization with the collaboration of Anatole A. Solow, distributed by Clearinghouse for Federal Scientific and Technical Information, U.S. Dept. of Commerce, Washington, D.C., November 1961

Analyzes advantages and disadvantages of an industrial park, manufacturing requirements, alternative locations in Nicaragua, and alternative sites in Managua. Contains detailed cost estimates for land and utilities. Methods of analysis and conclusions provide useful guidelines for other developing countries.

140. Organisation for Economic Cooperation and Development, Salient Features of Regional Development Policy in the United Kingdom, August 1967, 133 pp.

Statements made in April 1966 by members of the British delegation to OECD on problems encountered and policies followed in regional development, with a succeeding statement in August 1967 of intervening development.

141. Pennance, F. G., Housing, Town Planning and the Land Commission, The Institute of Economic Affairs, Ltd., London, 1967, 68 pp.

A review and analysis of the economic effects of the Land Commission Act in Great Britain. The author proposes to treat development rights in land as a salable commodity, arguing against the Land Commission acting as a land-holding agency. Favors more flexible town planning, building densities, housing standards, subsidies, and rent control.

142. Peters, G. H., Cost-Benefit Analysis and Public Expenditure, Eaton Paper No. 8, The Institute of Economic Affairs, London, 1966, 44 pp.

Comprehensive review of recent efforts to use cost-benefit analysis in water resource, transport, land use, and town planning situations. Calls attention to difficulties in the procedures and assumptions employed. The following sentence summarizes the types of problem for which proponents of cost-benefit analysis recommend this technique: "Cost-benefit analysis methods are advocated for dealing with projects in which investments are large and indivisible, in which group wants are catered for, where prices are not charged to consumers for use of final output or where there are important externality effects." Cites several studies of costs of expansion of cities of different size.

143. Prakasa Rao, V.L.S., Towns of Mysore State, Indian Statistical Series No. 22, Asia Publishing House, New York, 1964, 120 pp.

Application of statistical and geographic techniques in a detailed analysis of urban characteristics, including urban services.

144. Prakash, Ved, Financing New Towns in India, Ph.D. dissertation, Cornell University, New York, June 1966

Establishes a planning framework through which to integrate financial, economic, and physical aspects of decision-making for urban development. In this context, assesses the costs of new industrial town development in India. Concludes that costs of new towns have exceeded the communities' ability to pay, due to adoption of ad hoc functional standards, particularly for housing. Presents proposals for land and tax policy, flexible planning standards related to ability to pay, and an urbanization budget related to economic criteria.

145. Prest, A. R., and R. Turvey, "Cost-Benefit Analysis: A Survey," The Economic Journal, Vol. 75, No. 300, December 1965, pp. 683-735

Comprehensive review of cost-benefit analysis, its development, scope, and general principles. General techniques are given for specific studies of water projects, transport, land usage, health, education, research and development, and defense.

146. Rhoads, William G., and Richard M. Bird, "Financing Urbanization in Developing Countries by Benefit Taxation: Case Study of Columbia," Land Economics, Vol. XLIII, No. 4, November 1967, pp. 403-412

Theory and advantages of using a valorization tax on real property to finance urban capital improvements in newly developing countries. A description of its use in Medellín, Bogotá, and Cali, Colombia, is included.

147. Rothenberg, Jerome, Economic Evaluation of Urban Renewal: Conceptual Foundation of Benefit-Cost Analysis, The Brookings Institution, Washington, D.C., 1967, 277 pp.

Personal, social, and economic costs of slum life are examined in an integrated context as a basis for evaluating renewal measures. The approach is tested through case analyses of recent U.S. urban redevelopment projects.

148. Stanford Research Institute, The Arequipa Industrial Park, prepared for the Junta de Rehabilitación y Desarrollo de Arequipa, Arequipa, Peru, and the Instituto Nacional de Promoción Industrial, Lima, Peru, by Richard A. Boettcher and Luis Viladegut, assisted by Robert W. Davenport, under AID contract, Menlo Park, Calif., July 1964

As part of the Peruvian government's program for further industrialization and development of the southern region by attracting industry, this study analyzes the feasibility of establishing an industrial park in Arequipa. Examines cost and financial aspects, existing public utilities and services, specific locations based on the requirements of the firms most likely to locate there, estimated area occupied by each, projected increase in employment, and design criteria. Includes detailed examination of cost factors.

149. Stanford Research Institute, Future Urban Transportation Systems: Descriptions, Evaluations, and Programs, Final Report I, 426 pp.; and Impacts on Urban Life and Form, Final Report II, 380 pp., Menlo Park, Calif., March 1968

Analyzes the principal urban transport functions (e.g., flexible, short trip mobility in the central city; high volume, high speed commuter access) and examines possible innovations to improve the performance of each function. Explores legal, financial, and organizational innovations that might be required in both private and public institutions to bring about technological innovations. Priorities for research and development are indicated. The report includes detailed comments by members of the advisory panel established for the study, which was carried out on behalf of the U.S. Dept. of Housing and Urban Development.

150. _____, An Industrial Park Development Program for Central America, prepared for the Central American Bank for Economic Integration, Tegucigalpa, D.C., Honduras, by Keith E. Duke, Phillip L. Adams, and Robert W. Davenport, Menlo Park, Calif., 1964

This report considers the feasibility of industrial parks as a means of promoting industrial development in specific areas and locations, and makes estimates of the size, design, and approximate cost of parks. The survey covers size of town most suitable for location of an industrial park, specific site requirements, an analysis of patterns of industrial location in the capitals of five Central American republics, and physical infrastructure and its general influences on industrial growth and location of industrial parks in the region. Assumptions for cost estimates for various park facilities are explained in detail.

151. Stewart, Charles T., Jr., "Regional Allocation of Public Funds for Economic Development," Land Economics, Vol. XLIII, No. 4, November 1967, pp. 421-433

After discussing alternative policy goals, reviews techniques of employment shift analysis and minimum requirements analysis in planning local industrial development and supporting investment.

152. United Nations, Report of the United Nations Interregional Seminar on Development Policies and Planning in Relation to Urbanization, Pittsburgh, Pennsylvania, 24 October - 4 November 1966, ST/TAO/SER.C/97, United Nations, New York, 1967, 74 pp.

Contains summaries of papers presented at the seminar, including essays on industrial location, urban concentration, and provision of basic infrastructure.

153. United Nations Economic and Social Council, Committee for Industrial Development, Report of the Inter-Regional Seminar on the Role of Industrial Complexes in Economic Development, E/C.5/67, February 23, 1965, 28 pp.

Report of a seminar organized by the UN, held in Tashkent, capital of the Uzbek SSR from September 22 - October 5, 1964. Industrial complexes are analyzed in terms of their composition and methods of establishment. Uzbek is examined as a case study.

154. United Nations European Economic Community, Study for Promotion of an Industrial Development Pole in Southern Italy, 312/II/66-E, Brussels, January 18, 1966

Preliminary memorandum outlining a study by the consulting firm, Italconsult, to create an industrial center in the provinces of Bari and Taranto sufficiently closely knit to continue developing by the interplay of market forces once the nucleus has been established. The sector selected for promotion is heavy and medium mechanical engineering. The report stresses the method of promoting intermediate goods and services needed for the main sector. The memorandum summarizes the economic analysis used and the main findings, including the technical external economies necessary for the establishment of complex industries in an underdeveloped region. Infrastructural requirements are specified.

155. U.S. Congress, Joint Economic Committee, Hearings before the Subcommittee on Economy in Government, Interest Rate Guidelines for Federal Decision-making, Washington, D.C., 1968, 32 pp.

Review and evaluation of appropriate discount rates for cost-benefit analysis. Includes a survey of federal agency use of the discounting technique in evaluating future programs.

156. U.S. Dept. of Commerce, Area Redevelopment Administration, Centralization or Decentralization of Economic Growth, a staff study prepared by Victor Roterus, Washington, D.C., April 1965

The author notes that patterns of decentralization evolve naturally. There is a "self-generating momentum of the concentration itself." In the United States there has been no deliberate policy with respect to centralization or decentralization, but an increasing concern with problems of centralization as well as with more positive policies and programs to assist decentralized growth. Subsidies have tended to foster agglomerations by providing mass transits, thruways, slum clearance, and urban housing. The author feels that national objectives would best be attained through a policy of decentralization and regionalization.

157. U.S. Dept. of Housing and Urban Development, Urban Planning in Developing Countries, by Lloyd Rodwin, prepared for the Agency for International Development, Washington, D.C., 1966, 56 pp.

Ciudad Guayana is used as a case study to review what was done in Venezuela and how similar basic ideas and methods of urban planning might be used in other countries. Requirements for effective urban planning and how it may contribute to development are reviewed.