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GUIDELINES FOR PRELIMINARY APPRAISALS OF CAPITAL PROJECTS

Part II - Transportation Projects

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FOREWORD

The project analyst using these guidelines should first read Part I, General Guidelines. It provides insights into key considerations for preliminary project appraisals (PPA's) in all sectors.

The transportation project guidelines deal expressly with those matters relevant to transportation projects. They tell the analyst how to think about a project in transport; what to look for; and how to assure consideration of all elements essential to a PPA. They assist in identification of institutional, cultural, political, and other factors which can weigh heavily on a project. They encourage concentration on big issues in broad orders of magnitude, leaving details and matters of lesser importance to be explored in a detailed feasibility study.

I. GUIDELINES APPLYING TO ALL TRANSPORT MODES

Introduction

Transport service is a necessary -- but not sufficient -- precondition for most economic development. Investments in transport facilities can absorb a sizable, and often too large, proportion of the capital available in less developed countries. Care in selection of transport investments can save large amounts of capital.

In concept, the appraisal of transport projects does not differ from that for other investments, but it presents special difficulties of fact-finding and analysis due to the characteristics of transport, its interdependence with other economic sectors, the wide dispersion of its benefits, the multiplicity of public and private agencies involved in providing transport facilities and services, the variety of transport modes, and the need for intermodal integration of the transport system and coordination between transport and other sectors.

Steps in the Preliminary Appraisal of Transport Projects

Preliminary appraisals of transport projects include the following steps:

1. Identification -- in the light of macro and sectoral economic conditions -- of the need and the particular objective or objectives to be met. This step includes estimation of the transport demand to be satisfied; it may also, in certain circumstances, require the quantification of the transport project's role in a broader development proposal.

2. Quantification of the physical inputs and outputs of the specified project

3. Valuation of inputs and outputs, i.e., pricing of the project

4. Computation of measures of economic return

5. Examination of alternatives to verify the selection of the project

6. Sensitivity analysis

7. Evaluation summary.

While the above steps are discussed as discrete tasks that can be taken in the stated order, it should be recognized that in the course of carrying out these steps there will be considerable interaction. For example, in carrying out step 5, the analyst may find that other alternatives suggest themselves, so that he may find it necessary to return to step 2.

Definition of Project Purpose and Consideration of Alternative Solutions

Transport activity is useful only in its service to other economic, social, or governmental activities. Therefore, PPA's for transport require considerable attention to the general condition and development trends of the country's economy. This is facilitated by an economic development plan, and even more by a transport sector study and regional development plan. If no such ready references are available, it is necessary to collect from other sources sufficient information to understand the relationship of the proposed project to other activities in transport and to economic development policies and strategy, potentials and constraints elsewhere in the economy.

The transportation project usually is based on the seemingly obvious solution to a problem. To judge whether such a solution is the right one, the PPA must start with a definition of the project's basic purpose. That purpose, for example, is not "to provide a highway from A to B" but "to facilitate the production and marketing of specific crops" or to support whatever other activity appears to need transport service. Once the basic purpose is clearly defined, the project analyst can examine alternative means of meeting the need and decide whether the proposed project is the best solution under existing conditions.

Relationship of the Project to Macroeconomic Variables and Sectoral Conditions

The demand for and the supply of transport services are closely linked to macroeconomic matters.

- Lack of transport can constitute a bottleneck to economic growth. Growth in the demand for transport, on the other hand, is a function of the rate of growth and changes in composition of GNP.

- Planned changes in the structure of the economy, e.g., emphasis on manufacturing for export and the pattern of geographic distribution of production envisaged in the plan have important implications for transport project appraisals.

- The availability of government funds will limit transport investments.

- The government's monetary, pricing, and wage policies will heavily influence the costs of transport construction.

- The availability of foreign exchange and the realism of the exchange rate will affect the importation and cost of rail cars, trucks, fuel and other items required for transport.

- Government policies toward recovering the costs of services will determine road user charges -- tolls, fuel taxes, licenses, fees -- affecting the choice of modes by users of transport services.

The impact of general economic conditions, plans and policies goes far beyond the few items mentioned. The project analyst must view the project in relation to those macroeconomic factors likely to impinge directly on the project.

Fortunately, sector studies in transport are becoming more common. They will identify key macroeconomic factors bearing on the sector, as well as political, cultural, and institutional matters of importance. They will help the analyst to find the best solution by allowing him to see the project as part of the entire transport system of the country or a region thereof, or as part of a system encompassing several countries. A national transport sector survey will provide such data as:

- An inventory of existing facilities, including their state of maintenance and their actual and potential capacity

- The volume of traffic, its trend in the recent past (say, 5 to 10 years), its indicated future growth, and its relationship to capacity

- Organization and operating practices, regulatory and taxation policies, and any other factors affecting transport activities

- Costs of construction and maintenance for the several transport modes

- Plans for regional transport development within the country and with neighboring countries

- Indications of constraints -- financial, physical, managerial, institutional -- which limit transport development.

Exploring Alternatives

With a correct definition of the basic need to be met by the project and an understanding of the economy and its transport system, the analyst can explore alternative ways of meeting the need. Alternatives that should be examined include the following:

- Rationalization of rate and tariff structures, tax schedules or administrative regulations to foster more efficient utilization of existing facilities

- Improvements in maintenance, operation, or administration to increase the effective capacity of existing facilities

- Use of storage facilities to reduce peak transport needs

- Use of a different mode of transport and/or a different routing of traffic which would serve the purpose at lower cost (see chapter II)

- Changing the location (or even the nature) of planned facilities generating the transport need

- Changing the location of the proposed transport facility

- Modifying the scale or design standard of the proposed facility and providing its ultimate capacity by stage construction over a longer period of years

- A combination of two or more of the alternatives indicated above.

Each of these alternatives implies inputs (costs) and benefits, the latter in the form of an added receipt or an avoided cost. An effort must be made to place a value on each.

Identification and Measurement of Costs

The economic test for transport projects is their contribution to national income or economic development. The measure used for the PPA is the net national rate of return, i.e., the internal rate of return on the project with inputs and outputs valued in "real" terms (General Guidelines, chapter II). Other tests may also be used, such as the benefit-cost ratio (General Guidelines, appendix A).

As explained in the General Guidelines, the costs relevant to these economic tests are the resource inputs required for the project. These inputs must be supported by a reasonable engineering estimate of the material, labor, and equipment

inputs required for each element of the project during its lifetime. Wider margins of error are permitted in estimates for the PPA than for the feasibility study. However, sensitivity analysis should be employed in order to make explicit the effects of uncertainties on the rate of return, to identify the elements requiring more detailed investigation and to suggest appropriate measures to reduce risks (General Guidelines, chapter VI).

In order for the costs of the physical inputs of labor and material to be added up, they must be expressed in money terms and estimated separately for each year of the project's life to permit due allowance for the time value of money. (See the section on discounting in chapter III of the General Guidelines.) In calculating the business enterprise rate of return (BERR), inputs are valued at current market prices.

As explained in the General Guidelines, the calculation of the rate of return to the national economy (NNRR) requires that inputs and outputs be valued in real terms. Where market prices are not available or are not accurate measures of real costs and benefits, shadow or accounting prices must be employed. The true economic cost of the capital to be invested in a project is always the opportunity cost of capital -- that is, the rate of return to be obtained by marginal capital investments in the country, rather than the particular market rate of interest which the government or other borrower may have to pay under the special circumstances of the project. Unless the internal rate exceeds the opportunity cost of capital, the project is not a profitable one from a national economic viewpoint.

Use of opportunity costs rather than market prices may also be indicated for labor inputs in countries where unemployment or underemployment is extensive, especially if there are legal minimum wage rates.

Expenses which do not reflect the cost of economic resources to the national economy (but which are merely transfers of funds within that economy) must be excluded from the computation of real costs to the economy. The most important examples are taxes and similar levies, not only those separately stated but also those reflected in market prices; for instance, import duties included in the domestic price of equipment and supplies,

or fuel taxes, license fees, etc., included in the expense of motor vehicle operators and therefore in the private cost -- but not in the national economic cost -- of vehicle operation.

Finally, special care is needed to ascertain that all costs inherent in the project are considered. In some instances, execution or operation of a project involves external costs that are not paid by the project, but that are necessary to achieve the project's purpose; for example, construction and maintenance costs of an access road to a port, airport or railway station, or costs of additional equipment needed for road maintenance or for maintenance of increased railway rolling stock. Such costs are included in the NNRR computation, but not usually in the BERR calculation.

Where major elements of cost cannot be estimated with certainty, sensitivity analysis (see General Guidelines, chapter VI) should be applied. If the priority to be assigned to the project is highly sensitive to the uncertain elements of cost, these sources of uncertainty should be identified for more detailed examination in a full feasibility study.

Identification and Measurement of Benefits

In principle, the valid measure of economic benefits from a transport project is the net value added to the economy's output by the service the transport project supplies. Transport projects may yield substantial indirect benefits through the stimulus provided to economic development. The principal difficulties in measurements of benefits arise from the fact that the benefits of most transport projects are so widely dispersed among and within other sectors of the economy that it is not feasible to identify and measure them realistically. The analyst should go as far as he can in trying to quantify specific benefits, but selective judgments are also called for.

Benefits can more easily be calculated for projects whose benefits are not widely dispersed. Benefits can be traced for a transport project designed exclusively or mainly to support a geographically and economically separate economic activity; for example, the development of agriculture in an entirely undeveloped area or of market production in an area limited

to subsistence farming, or the development of a mine or an industry in a remote location. In such situations, however, the benefits and costs of the transport project should -- in most instances -- be consolidated with the other inputs required for and benefits arising from the development project.

The majority of transport projects are designed to provide, and most often to improve, transport service for a variety of economic activities. It is impracticable to trace all the consequent net additions to economic output that may be expected to accrue during the life of the transport facility. In these circumstances, benefits resulting directly from the improved transport service must then be used. Most important and most readily measurable are savings in operating expenses and travel time of freight and passengers which accrue to users of the facility (or of alternate existing facilities relieved of congestion). Reduced expenses for facility maintenance may also constitute an important source of benefits. Reduction of accidents and of damage to goods, and improvements in service reliability, convenience, and comfort also may represent real benefits, although they are rarely capable of precise valuation.

All these benefits are directly associated with the traffic served by the proposed new or improved facility. It is assumed that they correspond to benefits arising for the national economy because reduced transport costs presumably will be reflected in lower prices of goods to consumers or higher revenues to producers. Indirect benefits are properly considered, however, insofar as they exceed the mere reflection of direct benefits; that is, when the improvement of transport conditions stimulates additional productive activity.

With-and-Without Basis for Estimation of Benefits

In order to assess each of the benefits directly associated with an improvement in transport service, two estimates must be made: an estimate of benefit per unit of transport service, and an estimate of the volume of traffic to which the benefits apply during each year of the project's assumed life. These annual estimates are needed for comparison with costs because the time pattern of costs and benefits is not the same, and the difference in timing affects the present net value (or net cost) of the project. Derivation of unit benefits and

of traffic estimates differs among the several modes of transport and is discussed separately for each mode in following sections.

Benefits for each mode must be measured by the difference between the conditions that would prevail during each year of the project's life with and without execution of the project. That this is not the same as the difference between conditions before and after execution of the project is best illustrated by the example of benefits arising from savings in operating and maintenance costs associated with the improvement of a transport facility (a road, railway, port or airport) which is now serving a volume of traffic approaching its capacity. If this facility is not improved or expanded, growing traffic will result in increasing congestion and rising operating and maintenance costs. If the improvement project keeps these costs down or reduces them, the cost savings during each year of the project's life are measured by the difference between costs on the improved facility and those which would arise in the same future year in the absence of the improvement, not merely by the difference between present and future costs.[1/]

The with-and-without test applies not merely to the estimates of benefits per unit of transport service but also to those of traffic volume. If traffic increases are expected because of general economic expansion in the project's service area, estimates of future traffic must be derived from gaugings of (1) the current traffic and (2) its prospective rate of increase with and without execution of the project.

Even without execution of the project, increased economic activity will result in larger traffic volumes. The new or expanded transport facility may attract additional traffic from alternate routes or modes and may contribute to the stimulation of new economic activity. Traffic estimates, thus, must be a composite of (1) the traffic currently served and its prospective expansion (sometimes called the "normal" traffic), (2) any traffic diverted from or to the facility, and (3) any traffic newly generated by the availability of improved transport service.

1/ For a more extensive discussion of this important point see Hans A. Adler, "Sector and Project Planning in Transportation," World Bank Staff Occasional Paper Number Four, pp. 45ff.

Where information on traffic volume is available for a sizable number of past years, estimates of future normal traffic sometimes are made simply from the assumption that traffic will continue to increase at the average past rate. This is a hazardous assumption unless it can be shown that the rate of increase in traffic has historically exhibited a stable relationship to the growth in economic activity, and that the historical rate of growth in economic activity can be expected to continue over the period of the projection. Where these relationships cannot be shown and where information on past traffic is not sufficient for this kind of projection, other bases for projection are required. These are discussed in the modal sections.

Estimates of traffic diversion must take account of the fact that the choice of transport mode and route is made mainly by shippers and passengers on the basis of rates, fares, quality and availability of service, and the particular requirements of the consumers of transport services, although transport operators have some limited freedom to modify routing.

Newly generated traffic may add substantially to the benefits of a transport project, but it need not necessarily do so. Although the project may stimulate new economic development which would not occur without it, the benefits from such a development are not entirely attributable to the transport service improvement because many other inputs are also required.

Traffic projections for particular modes, and for components of any single mode, should be made in the light of the anticipated growth in overall traffic demands, in conjunction with an analysis of the transport network as an integrated supplier of transport services. The construction of a new road link or a bridge, for example, can have an important effect on traffic growth on not only connecting roads, but also on the traffic demands on rail and port facilities.

If information on origins and destinations is available -- or can readily be collected -- it can be useful in developing a basis for the "assignment" of traffic, present and projected, to routes and modes that will facilitate the achievement of the most economical intermodal arrangements. This type of analysis can be most useful in appraising the relative merits

of transport projects in terms of how well they conform to the expected spatial pattern of demand for transport services.

Economic Criteria

When benefits have been identified and measured to the greatest extent possible and values have been placed on the estimates, the annual value of these benefits should be entered in tabular form, such as that suggested in chapter VII of the General Guidelines. Together with estimated values of inputs, by years, these data form the basis for the quantitative PPA, in terms of internal rates of return to the enterprise and to the national economy as a whole.

The identification and measurement of benefits from transport projects involve numerous and difficult judgments. Presentation and statistical manipulation of a wealth of data -- or of statistically expressed assumptions in lieu of unavailable data -- are no substitutes for incisive economic analysis. As in other types of projects -- although to a greater degree because of the widespread diffusion of benefits -- PPA's in transport involve more than mechanical computations. At the same time, such computations, based on carefully made quantifications of costs and benefits, provide an essential element in the process of project appraisal.

Divisibility and Timing of Transport Investments

Proposed transport projects often have several separable components. Each of these components should be appraised separately One component (e.g., one new wharf) may show a high net benefit, or rate of return, and the second component (a second wharf) a much lower or even negative one. Even though the net benefit of the entire project (consisting of two new wharves) may seem satisfactory, only those components that show a satisfactory net benefit by themselves should be executed. Computation of discounted present net values for increments of investment can provide guidance in choosing the most beneficial combination of components in the project (General Guidelines, chapter IV).

Stage Construction

Very often, a component which does not show a satisfactory benefit at the time of the PPA may do so at a later stage in the economic development of the country. Proper timing of transport investments may require stage construction; for example, one wharf constructed now, with the second being constructed in 5 or 10 years; or one stretch of highway or railway line constructed at the outset and another after 5 or 10 years; or a lower grade road built first which will be upgraded later. Resulting increases in total construction cost may be far more than offset by the net returns to the capital employed in an alternative project during the period of deferment. Computations of the discounted (at the opportunity cost of capital) net present values for immediate execution of the entire project and for stage construction will provide guidance for selection of the most economical phasing.

Even if the opportunity cost of capital is as low as 10 percent per year (and in most of the less developed countries it is between 12 and 15 percent), a million dollars invested today must return $331,000 within the first 3 years. That amount is wasted if the investment is made 3 years before it is needed. Stage construction can often minimize such waste of capital, either by construction of part of the facility initially and expansion of it later, or by provision of a low-grade facility first and improvement of it when a larger transport demand is to be satisfied.

II. INTERMODAL COMPARISONS

Comparisons of the costs and benefits of meeting identified transport requirements -- present and projected -- by alternative modes are an essential component of the project appraisal. For example, shipments of oil products from a refinery can be accomplished by one or more of the following modes: roads, barges, railroad, or pipeline. Ore may be shipped by road, by rail or by both modes or in slurry pipelines. Selection of the optimum transportation mode or a combination of modes is dependent on several variables. These variables are

- Kinds of products to be shipped
- Expected economic life of the alternative transport facilities
- Other uses for which the transportation facilities can be utilized, e.g., transportation of persons
- Distances for movement
- Quantities of the products to be moved in a given time
- Value of the product
- Impact of the alternate modes on general economic development and national integration.

If the volume of shipments is large and destination points fixed and comparatively few in number, the movement of refinery products from location A to location B may warrant construction of a pipeline. On the other hand, a railroad provides flexibility for movement of other products and passengers, thus providing a viable economic instrument to facilitate the development of a region. Short distances of movement with a diversity of destination points may warrant consideration of movement by road transport on highways, involving new construction or improvement of existing highway networks. Railroads and highways may be used to move other products and provide passenger transportation links.

A simplified form of analysis that can be made for single product movements is shown in figure 1. The unit cost of shipping a product in dollars per unit is measured on the vertical axis, and distance on the horizontal axis. Each of the cost curves represents a different mode, for instance, road transport (A), rail (B), and pipeline (C). A series of break-even points can be identified. Between these points a given transport mode is preferable from a cost standpoint.

Comprehensive analysis must be made, of course, of intermodal transportation requirements in addition to distance, e.g., size of shipments, total annual volume of traffic, perishability of commodities, and speed. Discussion of these complex relationships is beyond the scope of these guidelines; however, it must be noted that careful analysis must be made and included in support of the mode selected in the project proposal.

In LDC's those transport modes that facilitate overall economic development should be given careful consideration. Thus, a road may be preferable to a railroad link and, in turn, a railroad may be preferable to a pipeline because of the development impacts of these modes. Cost-effectiveness can be utilized in arriving at an assessment of the most economical means of providing the required transport service, including newly generated traffic.

In the search for the least-cost mode for effecting given commodity movements, attention should also be directed to the possibilities of economies (and diseconomies) of using more than one mode for the movement; e.g., a combination of highway and rail transport may provide a lower total cost for the movement than exclusive reliance on either railway or road transport. The economies of road transport in handling small lots over short distances and the cost advantages of carload railway shipments over longer distances must be weighed against the additional costs of transshipments from one mode to another and the (probable) losses from breakage and theft with multimodal shipments.

The choice of one mode over another or a combination of modes should also take into account the costs of distribution associated with the alternatives, e.g., warehousing, storage costs, the costs of capital tied up for longer periods of time in the use of slower modes, etc.

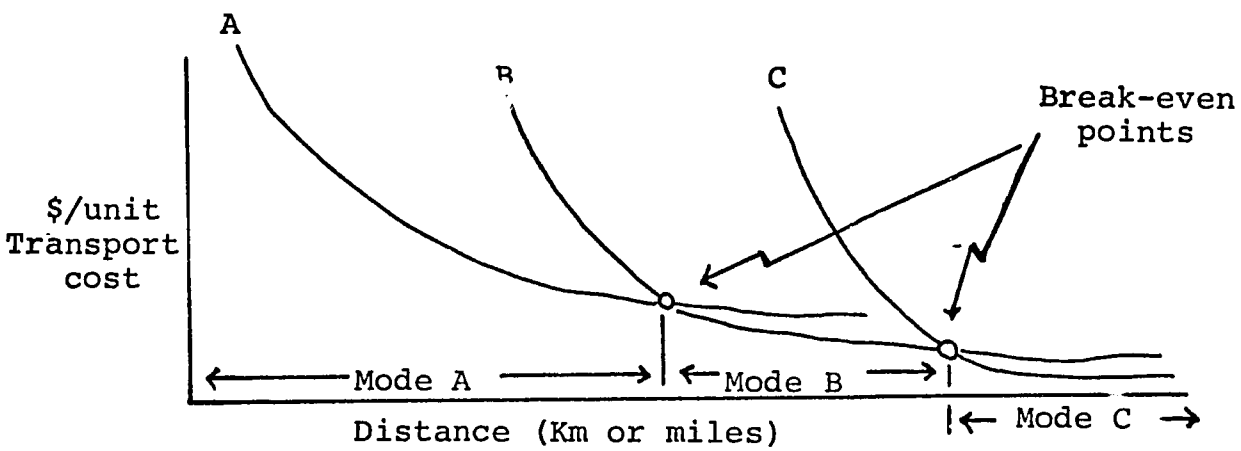

Figure 1. Simplified Form of Analysis for Single Product Movements

III. HIGHWAY PROJECTS

Introduction

Many of the special problems encountered in highway project appraisals arise from the fact that highway facilities are provided and maintained by some governmental entity but are used for highway transport by relatively large numbers of private and governmental operators for a great variety of economic and noneconomic purposes. Economic appraisal needs to take account of both facility investment and operations. Because of the separation of responsibility for these two aspects, substantial research is usually required to collect the necessary data.

The economic justification of highway projects depends crucially on the relationship of the highway capacity to be provided (which determines the investment needed) and the volume and character of the traffic to be served (from which the benefits will be derived). The relationship of capacity to traffic appropriate for LDC's differs from that applicable in advanced economies because of: (1) the higher opportunity cost of capital, (2) the lower labor cost, and (3) the greater uncertainty about traffic development in the LDC.

The PPA for highways -- like other project appraisals -- should include an evaluation of (1) the technical feasibility of the project, (2) the economic costs and benefits of the project, and (3) the financial feasibility of the project.

Each of these aspects is discussed in the following sections, with special reference to preliminary appraisals of highway projects.

Technical Feasibility

While it is physically possible to build a road under most natural conditions, it may be prohibitively costly where conditions are unfavorable. In any case, the costs of construction, maintenance, and repair are heavily influenced by topographic, ground and subsurface conditions. Therefore, the procedures

and data employed in site evaluation and the conclusions reached should be examined in the PPA from the standpoint of their influence on the costs of the project.

Site evaluation should include a review of the following factors: (1) topography; i.e., the extent of flat ground and slopes; (2) ground conditions, especially bearing strength and ease of excavation and stabilization; (3) drainage of the surface and subsurface and elevation of the water table; (4) weather conditions, including amount and distribution of precipitation; (5) clearing needs concerning both vegetation and structures; (6) availability of surface and ground water for consumption and construction use; (7) availability of natural and processed construction materials; and (8) interfaces with existing or planned roads and highways.

Topographic maps of a 1:500,000 scale are sufficient for a PPA (although not for design and construction planning) but they should show contours at less than 20-foot intervals, and preferably at 5-foot intervals, to provide adequate information on such features as ravines, low escarpments, rock knobs, and sinkholes. Geologic maps, especially if made on a topologic base, provide general information on the nature of the landscape, the character and drainage of subgrades, and the nature of the foundation (distinguishing rock, soils derived from rock and transported soils). This information can be refined by the use of soil maps.

Where the area is not accessible to ground survey parties and map information is inadequate, it may be supplemented or even replaced by clear stereoscopic aerial photographs. The features they show can be interpreted to provide much information useful in arriving at order of magnitude estimates of construction costs.

A more detailed discussion of soil types, the availability of water, and construction materials commonly associated with various types of terrain is presented in appendix A.

Traffic Projections

Traffic estimates are a key element in any highway project proposal. They provide the basis for: (1) determining the

highway capacity required, (2) quantification of the benefits to be expected from its utilization, and (3) evaluation of the adequacy of the proposed project. To measure benefits, estimates of prospective traffic demand must be made both with and without execution of the project, as is described in the section for all transport modes. These estimates need to be built up from separate components representing normal, diverted, and generated traffic.

All these estimates must be developed by a combination of experienced judgment with careful analysis of a sizable amount of traffic and economic information. If all of the necessary traffic information has been collected completely and reliably for a few years -- origin and destination data, detailed traffic counts by type of vehicle, purpose of trip, and hourly, daily, and seasonal variations -- the analyst can proceed to relate each of the various traffic components to its economic or social determinant -- such as business or pleasure travel, delivery of specified products, etc. -- and can estimate the prospective volume of each type of traffic on the basis of economic data indicating the probable rate of growth in the relevant economic activity. Traffic not directly related to a specific activity usually can be expected to grow with the income of the relevant group of travelers or consumers, although not necessarily in direct proportion.

But information in the required depth and detail is seldom available in LDC's. The information gaps cannot always be closed by the collection of primary data even in the context of a full feasibility study, and certainly cannot in that of a PPA. The analyst must rely on a generally less satisfactory data base in developing projections of future traffic. Correspondingly greater responsibility, therefore, is imposed on the judgment of analysts preparing and appraising traffic estimates.

There is no substitute for at least a minimum of traffic information which can be provided by classified hourly counts and O/D surveys for a week or two at a few stations. The design of such a minimal survey should be based on a discussion with informed people (local police, highway and other officials, service station attendants, regularly traveling bus and truck drivers, etc.) on the general characteristics and composition of the traffic. After the survey, further interviews with

similar sources, and especially with managers of relevant enterprises, should be undertaken to determine how representative the survey period traffic can be assumed to have been. Techniques for traffic estimation suitable for use in LDC's are presented in appendix B.

Preparation and appraisal of traffic estimates cannot be limited to a series of routine statistical procedures. Traffic analysis requires an understanding of each significant traffic stream, its variations and composition, and the economic factors that generate it and those that will affect it in the future. Such an understanding often will reveal alternative ways of meeting the prospective traffic demand in more economical ways.

Design Standards and Highway Capacity[1/]

Economic justification of any highway project depends crucially on the proper relation of the proposed design standards to the prospective traffic demand. Therefore, for the PPA, it is necessary to assess the proposed design standards to ascertain that the proposed facility is neither overdesigned nor underdesigned in relation to the projected traffic demand.

Design standards have many components. Most important are the width and surface characteristics of the traffic lanes and shoulders, horizontal curves and vertical grades, and sight distances. These characteristics determine how fast a given vehicle can safely and conveniently travel over the highway under various traffic conditions and, therefore, also the number of vehicles the highway can accommodate in a given period of time -- i.e., the highway's capacity.

The most extensive and thorough engineering research on the relation of design characteristics to highway capacity has been conducted in the United States. Many of its results are readily applicable to conditions elsewhere, since they are concerned with physical rather than economic relationships.

1/ For detailed tables showing relation of capacity to geometric design characteristics for rural roads and urban streets in LDC's, see appendix C.

It does not follow, however, that the design standards recommended to meet a given traffic demand in the United States are appropriate also for LDC's. Costs of capital are substantially higher in these countries; productivity, on the other hand, is lower, so that both time saving and convenience in highway travel have a lower value. For any given traffic demand, therefore, design standards used in LDC's generally should be lower than those used in the United States.

In relating traffic demand to highway capacity, both composition and timing of traffic need to be considered. The larger the proportion of slower-moving heavy vehicles, the lower will be the practical capacity of a highway of given design; also, the larger the proportion of heavy vehicles, the higher will the design standard have to be to permit the same average travel speed for a given volume of traffic.

Selection of design standards should be made with a view to the possibilities for stage construction. Those basic elements of the road that can be upgraded only at a disproportionate cost, if at all, should be designed for the capacity eventually needed. They include the alignment, especially the horizontal and vertical curvature; the right-of-way; and the earthwork to provide the eventually required roadway-formation width. Elements that should be deferred until the larger capacity is actually needed include part of the pavement width, the shoulder stabilization, and some miscellaneous features such as guardrails, headwalls, fencing, lighting and slope protection. The outlay involved in providing them later will be somewhat higher, but the cost difference will be more -- often far more -- than offset by the saving in capital cost resulting from the deferral.

The significance of savings available from stage construction is illustrated in table 1, adapted from findings of a study in Malaysia[1/] where the opportunity cost of capital in 1967/68 was assumed to be only 10 percent; nevertheless, a net saving was found to result from building roads initially

1/ Robert R. Nathan Associates, Inc., and Frederic R. Harris, Inc., Transport Development in Malaysia, (Washington, D.C., 1970) Vol. 2, pp. 94 ff.

Table 1. Savings Obtainable From Stage Construction

Type of construction	Cost in US$/mile		Net saving c/	
	Amount a/	Present value b/	$/mile	percent
Minor road (up to 400 ADT)				
Initially to full standard	68,300	68,300	-	-
One standard lower for 5 yrs.	73,300	61,100	7,200	10.5
Two standards lower for 5 yrs.	75,600	60,900	7,400	10.8
One standard lower for 10 yrs.	73,300	53,600	14,700	21.5
Two standards lower for 10 yrs.	75,600	51,900	16,400	24.0
Two-lane highway (up to 800 DHV)				
Initially to full standard	107,300	107,300	-	-
One standard lower for 5 yrs.	115,900	98,400	8,900	8.3
Two standards lower for 5 yrs.	120,700	97,200	10,100	9.4
One standard lower for 10 yrs.	115,900	87,600	19,700	18.4
Two standards lower for 10 yrs.	120,700	82,700	24,600	22.9
Four-lane highway (over 800 DHV)				
Initially to full standard	183,000	183,000	-	-
One standard lower for 5 yrs.	219,700	173,500	9,500	5.2
Two standards lower for 5 yrs.	228,200	168,200	14,800	8.1
One standard lower for 10 yrs.	219,700	144,900	38,100	20.8
Two standards lower for 10 yrs.	228,200	121,800	51,200	28.0

a/ The costs first shown above include, alternatively, (1) the amount required for initially constructing the road to the full standard indicated and expected to be eventually required, or (2) the amount required for initially constructing the basic elements to the same standard, but the deferrable elements only to the extent needed for operating the road at one or two standards lower plus the amount required for upgrading to full standard after 5 or 10 years.

b/ The present values shown represent the sum of the initial expenditures plus the present value of subsequent upgrading costs, with the latter discounted to the present at 10 percent per year.

c/ The net savings compare the present value of the indicated type of construction with that of initial [illegible]

only one standard lower than those needed, and upgrading them only 5 years later. The saving will be larger where the cost of capital is higher.

Apart from checking for the internal consistency of proposed design characteristics, the PPA should apply two tests: First, the traffic volume for which the road is designed should be compared with the traffic forecast, in terms of average daily traffic volume (ADT) for less heavily traveled roads, and in terms of design hour volume (DHV) for more heavily used highways. This comparison will show whether the traffic volume for which the road is to be provided will be reached within a reasonable number of years. Second, it should focus on the operating speed that is anticipated. Too low a design speed results in inefficient traffic operation; too high a design standard involves a wasteful capital investment.

Construction and Maintenance Costs

Cost estimates for PPA purposes are best provided and checked on the basis of modules. The appropriate module for both construction and maintenance of roads is the cost per mile. Cost estimates per mile, however, are meaningful only if it is clear that they cover all cost elements, are properly related to the characteristics of the project, and are based on reliable information adjusted to reflect local unit prices of materials, labor, fuels and other components in the cost modules.

In order to be complete, estimates must include the costs of (1) planning and design, (2) purchase of the right-of-way, (3) initial construction, (4) subsequent upgrading, and (5) adequate maintenance. The best sources of information on all cost elements are records of recent and comparable experience in the same country. When estimates must be based on other sources, these should be clearly identified and the manner in which original data have been adjusted should be explained. For the purpose of calculation of the MIRR in a PPA, cost data also must be adjusted to exclude taxes and to allow for the application of shadow prices as appropriate. (See General Guidelines, chapter II and appendix B.)

Construction Costs

The cost of construction varies widely, depending on the type of road and on local conditions. The amount of grading required, the width and thickness of the surfacing, the wages paid, the productivity of labor, and the availability of materials all have an influence on construction cost. It is, however, possible to give a general average of the cost for each type of road as constructed all over the world to serve as a general index of cost relationships among road types. Such data are presented in table 2.

Table 2. Average Costs of Constructing Roads in Flat Terrain (Based on or Adjusted to Costs in 1968)a/

(per mile)

Type of surface b/	Average construction cost per mile of road (24 feet wide)
Sand-clay, untreated.....	$31,400
Sand-clay, treated.....	36,800
Gravel, untreated.....	45,000
Gravel, treated.....	67,400
Macadam, untreated.....	67,400
Macadam, treated (secondary roads) c/	89,800
Low-cost bituminous mixtures.....	54,000
Bituminous macadam.....	110,500
Bituminous concrete (primary roads-medium type).....	131,000
Cement concrete.....	157,000

a/ Developed from Ralph M. Parson Company cost data.
b/ The volume of traffic that can be accommodated by these surfaces will vary according to the geometry of the road. No quantitative value for road capacity can be given when only the surface type is known.
c/ More data on these types of roads are provided in table D-1.

An illustrative set of estimates for several types of roads in varied terrain is shown in appendix D, table D-1.

A number of useful tables indicating order-of-magnitude cost modules in some detail are presented in appendix D. The values shown in these tables are averages which must be checked against local unit prices.

The average prices shown in appendix D, tables D-1 through D-5, have arbitrarily been assigned a location factor of 1.00. Factors for a number of geographic locations in LDC's are indicated in table D-6. These location factors were developed from actual bid experiences and reflect all of the intangibles that account for price differentials between geographic locations. If any of the unit prices shown in the preceding tables are used, they should be multiplied by the applicable geographic cost factor shown in table D-6. In addition to adjustments to reflect country-to-country variation, correction factors for changes in prices should be applied also.

Although the average cost information, percentage composition of costs, and cost differentials associated with location are useful in the PPA, they have limitations. It must be clearly understood that the use of such broadly based averages in lieu of reasonably well prepared information on the cost factors prevailing in or near the project area is, at best, a poor substitute.

Maintenance Costs

Locally based information is even more essential for the appraisal of maintenance costs than of construction costs. Maintenance has a much larger component of labor cost and is almost always carried out by indigenous (usually governmental) organizations with local labor. Records on maintenance expenditures require careful review before their end results can be used because they often fail to include all the costs of road maintenance. Appropriate allowances for depreciation of machinery and equipment used in maintenance, and an allocation of administrative costs, are frequently omitted.

Approximate surface-maintenance costs per mile for various types of surfacings are shown in table 3. These costs are based on values compiled from reports of several highway organizations in the U.S. and in other countries. In addition to the expense of surface maintenance, the total cost includes such items as the cost of maintaining the base and the roadside, the cost of betterments to the road, overhead charges, and the cost of work on drainage structures and snow removal. Such general items will cost from $865 to $1,730 per mile per year.

Table 3. Approximate Surface-Maintenance Costs on Roads

Type of surfacing	Annual surface-maintenance[a] cost per mile of road (24 feet wide)
Sand-clay, untreated.....	$1,340 to $2,670
Gravel, untreated.....	2,010 to 3,120
Waterbound macadam, untreated.....	2,130 to 3,340
Surface-treated types.....	1,120 to 2,010
Bituminous road mixes.....	888 to 1,520
Bituminous macadam.....	667 to 1,360
Bituminous concrete.....	446 to 890
Cement concrete.....	335 to 667

a/ For estimated total maintenance cost, add $865 to $1,730 to these numbers.

In interpreting maintenance costs, it is essential to consider the amount of traffic to which the various surfacings are subjected. For example, the maintenance cost of a hard-surface pavement on heavily traveled highways could be about the same as those for sand-clay roads with very light traffic. However, the maintenance cost per vehicle is much less for hard pavement than for sand-clay.

The Benefit Estimates

Most of the basic issues encountered in the appraisal of benefits from road construction and improvements are similar to those raised by other transport projects.

Benefits (and costs) of transport projects proposed mainly to support a geographically isolated economic development cannot be segregated from the benefits (and costs) of the entire development. In the following discussion attention is focused on the quantification and valuation of benefits from road projects designed to provide or improve transport service for a variety of activities already conducted or presently developing in the road service area. The ultimate economic effects of such transport service are widely dispersed, and accrue to those who do not, as well as to those who do, make direct use of the road. In estimating the benefits from the facility, the PPA must be based on the benefits directly associated with the service, notably the savings of expense and of time accruing to direct users of the road.1/ Their expenses are determined by the type of vehicles they use, the load factor, the condition of the road, the terrain, the composition and density of traffic, and the distances they travel. The unit of transport service most convenient for consideration of all of these variables is the cost of operation per vehicle-mile.

Since vehicle type is one of the variables affecting road transport cost, operating costs per mile must be considered separately for various vehicle types. At a minimum, a distinction must be made between light vehicles (passenger cars, small buses, and light delivery trucks and similar vehicles usually built with passenger car engines and chassis) and heavy vehicles (large buses, trucks, and tractor-trailer combinations). There are, of course, differences among light vehicles, but they are not enough to matter for a PPA. Thus, all light vehicles may be represented by a single one typical of the traffic or, better, by a weighted average of two or three types widely used in the service area. Differences among heavy vehicles are substantial, however, and it is desirable to use separate unit values for two or three of these types, provided that traffic information is correspondingly detailed. Otherwise, an average will also have to be used for heavy vehicles. Such an average, however, should be based not only on vehicle types actually used in the service area; an effort should also be

1/ The direct benefits accruing, in the first instance, to the users of the highway -- particularly for goods transport -- may be disseminated to a much broader segment in the form of reduced costs of goods purchased and/or higher prices for goods produced, made possible by reduced costs of transport.

made to approximate the proportion in which they are present in the area traffic and to apply corresponding weights in computing average unit costs. Special attention must be paid to the proportion of diesel-powered units; it often is significant among heavy vehicles and in some countries also among lighter ones.[1/]

The effect of road conditions on operating cost also has several dimensions. Most important is the difference among road surfaces. According to a World Bank Staff Paper,[2/] improvement of an earth road to a gravel road can be expected to save light vehicles 22 percent and heavy vehicles from 30 to 43 percent of their operating expenses; corresponding savings from changing a gravel road to a paved one are 22 percent and from 26 to 37 percent; changing an earth road to a paved one may save 39 percent and from 48 to 64 percent. Less dramatic but still significant cost differences arise from the geometric characteristics of roads. Rise and fall and curvature have some modest direct effect on vehicle operating expense. In addition, these characteristics, together with road width, sight distance and surface condition, affect the speed at which traffic can move and thus the cost of operation.

Operating costs also are influenced by traffic conditions. The most important factor in the majority of LDC's is the composition of traffic: the proportion of heavy vehicles which tend to delay all traffic movement, especially on narrow roads and substantial grades, and the presence of nonmotorized traffic (including pedestrians) which may impede traffic movement even more. In LDC's, traffic volume on most roads (except those in the vicinity of the larger cities) is so low in relation to the capacity of otherwise satisfactory roads that it rarely causes any significant delay.

The effects of road and traffic conditions on the running speed and, hence, operating expenses of various types of vehicles has been studied in many countries, most extensively and thoroughly in the United States. Although the published results must

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1/ Widespread use of light diesel vehicles is almost always an indication of preferential taxation.
2/ Jan de Weille, "Quantification of Road User Savings," World Bank Staff Occasional Paper Number Two, p. 31.

be adjusted insofar as they reflect U.S. economic conditions, the underlying physical relationships are generally applicable. The effect of road and traffic conditions on travel speed and on consumption of fuel and oil, tire wear, vehicle life and maintenance, and on time consumed in travel are virtually the same in all environments but the most unusual ones (e.g., deserts or arctic wastes). However, the values to be placed on time saved will vary greatly between countries. Prices of vehicles, fuels, tires and lubricants will also differ among countries, and the pricing of the savings in wear and tear and fuel consumption must take local prices for the valuation.

Some studies assign equal values to the time of all drivers and passengers, based on the assumption that leisure time is as valuable as working hours. This view is not universally accepted. Some regard it as unjustified to assign so high, if any, a social value to leisure time in countries with large numbers of unemployed and underemployed persons. The value to be assigned to driver and passenger time saved should be decided in view of local economic conditions and the purposes of passenger trips. It is recommended that the analyst exercise restraint in the valuation of passenger time saved.

Vehicle operating cost data that may be found useful in the absence of specific local information are presented in appendix E.

In addition to the procedures thus far discussed, benefit analysis often is also concerned with travel distance. This may be shortened either by improving the alignment of the road that would in any event be used by the traffic, or by providing a shorter connection for traffic which previously was compelled to use a circuitous route. Especially in the latter case, distance savings may substantially contribute to the cost saving benefits of a project. The full cost of the trip over each route must be computed and the difference multiplied by the number of trips. Comparison of total trip costs is also necessary for computing benefits accruing to traffic diverted from another mode.

Apart from the tangible savings to road users, improved road service provides a variety of other benefits to them and to others, including comfort and convenience. Like the amount

allowed for time savings, these are benefits whose social value in developing countries may be questioned. Less questionable is the benefit from reduction of accidents and damage to goods; it is, however, a difficult benefit to measure.

In the assessment of benefits, perhaps the best procedure is that which confines the value estimates of benefits used for the basic justification of the project to those that can reliably be established; other anticipated benefits might be noted and the best estimates of their value provided for use in the sensitivity analysis.

Economic Appraisal

The results of the economic appraisal should be summarized in the form of the computed NNRR; this measure, based on real social costs and benefits, will facilitate comparisons with similar rates for projects in other sectors, and with other transport projects. Other measures may also be computed, if desired, using the same basic data from the tables described in chapter VII of the General Guidelines. In those cases in which quantification and valuation of benefits do not yield meaningful results, emphasis should be placed on the development of least-cost alternatives to provide the service.

Financial Feasibility

A review of the road tax situation in the country is also needed in the check of the financial feasibility of the project. Although added traffic generated by improved road conditions will increase the government's revenue from road user taxes, these transfers of funds from road users to government are not a gain for the national economy and play no direct role in the economic justification of the project. They do, however, make it easier for the government to carry the financial burden resulting from the road investment, or at least that part which arises from domestic expenditures. Moreover, the way in which these transfers are effected will influence the use of the facility and therefore the net social gains realized from the project. The financial analysis also should examine other budgetary resources for covering both domestic and foreign exchange costs and should relate the foreign exchange requirement to the country's prospective balance of payments.

Evaluation Summary

The results of the PPA, including noneconomic aspects, as well as the rate-of-return calculations should be summarized for presentation to decision-making authorities. Suggested forms are shown in chapter VII of the General Guidelines.

IV. RAILWAY PROJECTS

Introduction

The basic considerations relevant to all transport projects are applicable, in general, to the preliminary appraisal of railway projects, with due attention to the particular characteristics of railroads. This section is designed to point out the more important of these characteristics as they affect railway projects and the tasks of making appraisals.

Characteristics of Railways and Railway Projects

Railway project appraisal is facilitated by the fact that almost everywhere a single organization is responsible for the provision of both railway facilities and railway operations. In important ways this makes a PPA for railway projects somewhat simpler than for highway projects.

Almost invariably a sizable amount of basic data on railway traffic, operations, and costs is recorded in the course of the railway's daily business. There is also a well-established tradition of periodic reporting and analysis of railway operating results. These reports can be helpful even though their dependability and timeliness vary widely and the traditional forms of reports and methods of analysis do not always lend themselves readily to economic assessment.

Entirely new railway projects are not frequently proposed. More often, railway capital projects involve extension, improvement, or rehabilitation of facilities and acquisition of rolling stock.

The PPA for an improvement or rehabilitation project inevitably will have to consider the physical, operating, and economic condition of the entire system, although the project proposal may be couched in much narrower terms. Most railways in LDC's were built at a time when railway construction and operating technology, as well as economic conditions, were quite different from those prevailing today. Management practices

adopted in the railroad's early days in many cases have changed too slowly, if at all, and improvement of the railway's service to the economy may depend on modernization of management and operations as well as on investment of capital in physical facilities. In the examination of alternatives, this possibility merits special attention.

In LDC's many railroads were built before efficient road transport was available. These railroads now find it difficult to maintain their position in competition with road transport, even though that competition in many cases has been impeded by restrictive regulations favoring railroads. Some of these railroads no longer perform a substantial and useful service; new capital invested in their rehabilitation or improvement is justified only if it can be demonstrated that existing and prospective traffic demands can be served more economically by rail than by alternate modes -- usually road transport. It does not follow, however, that railroads generally are outmoded. They still are able to provide many transport services at lower cost than trucks, especially in moving heavy bulk goods over substantial distances and with reasonable regularity.

Railroads in LDC's are generally well placed to provide bulk service from production centers for primary products to export points and to consumption centers which have developed in or near port areas. They also can supply local transport service to the areas they traverse if these areas have not been penetrated by the road network. However, as noted earlier, railways constructed to meet the needs arising in an earlier stage of development may not be ideally located to serve the needs of a more highly developed internal economic structure. Nevertheless, while the economic sectors to which railroads can offer the lowest cost transport service may be limited in number, these sectors may continue to be of strategic economic importance.

In most LDC's, projects to upgrade rail facilities, such as installation of heavier rails, signalling and communication equipment, locomotives and freight and passenger cars, will have a very high foreign exchange content. The PPA should take special cognizance of the country's ability to meet the foreign exchange costs, from its foreign exchange reserves, expected current foreign exchange earnings, or from loans. Because of the importance of foreign inputs relative to total

investment costs of such projects, the use of a realistic foreign exchange rate in the pricing of the imported inputs is critical. A shadow or accounting rate of the exchange may be required (see General Guidelines, appendix B). Producers of railway locomotives, rolling stock and equipment frequently offer credit terms on the sale of their products. In the financial appraisal, if such terms have been proposed they should be carefully examined in light of: (1) the projected flow of funds available for debt service, and (2) the costs, including interest, of alternative sources of equipment. Favorable credit terms -- extended grace periods, long maturities and low nominal rates of interest -- may be more than offset by excessively high prices charged for the equipment; "free" technical assistance offered in connection with equipment should also be scrutinized for the same reasons.

Technical Feasibility

The physical conditions -- terrain, soil types, drainage, etc. -- affecting the feasibility of the provision of a railway line at reasonable cost are in many ways similar to those applying to highway construction. In an appraisal of the technical feasibility of a railroad project, attention also needs to be given to the technical requirements of operation after construction is completed. These include not only the need for additional rolling stock (which usually must be imported) but also the system's readiness to supply the necessary technical and managerial manpower and to maintain track and rolling stock efficiently.

Design Standards and Capacity

For the purpose of investment analysis, the capacity of a railroad is measured by the volume of traffic that it can handle within a given period and at lower cost than any other transport mode that is available (or could be made available) to serve the same traffic. Cost in this context includes not only the expense of railroad movement itself but also any other cost that will be incurred to supply the transport service concerned (e.g., delivery to and from stations) and, whenever it is significant, the cost of differences in time elapsing between dispatch and delivery.

Numerous physical and operational factors within the railroad system itself affect capacity, and the many interactions among these factors provide opportunities for tradeoffs among them. The PPA analyst may find that construction features which involve a sizable capital investment may be replaced by less expensive modification of other design elements or by changes in the prevailing or anticipated operating practices (e.g., improved couplings to permit longer train units, or better signalling and communications).

Many railways in LDC's are limited to a single track over most of their system. Obviously, capacity would be very sharply increased by double-tracking of an entire line. However, it may be sufficient to double-track a short section which carries especially heavy traffic or to provide more double-tracked passing sections. Where the train control system is outmoded, signal improvement to permit train movements at shorter intervals may be the most effective and least expensive means of providing the required increase in capacity.

The combination of track and signals determines the number of trains that can move over the line in any given time. The same number of trains can move larger volumes of freight, however, if train capacity is raised, which can be done in a variety of ways. Train length in some instances is limited merely by tradition or institutional factors, even though engines with greater motive power already are available or are to be provided as part of the proposed project. Train length may also be limited, however, by the length of existing passing sections, suggesting their extension as a relatively low-cost means of improving capacity. In other situations, steep grades or sharp curves may preclude the use of longer trains or higher speeds; unless such grades or curves are too numerous, an improvement of the alignment may be worth considering.1/

Longer trains may require stronger engines, but very often engine capacity is not fully used. The removal of other

1/ In constructing a new line, bridges or tunnels can provide an alignment which avoids steep grades and sharp curves. The increase in construction cost that is entailed must be balanced against the increase in capacity and reduction in operating expense.

constraints which preclude longer trains may make the use of such trains feasible without new engines or with the new engines to be introduced as part of the project under consideration. In any event, removal of over-age engines and replacement of steam engines by diesel units are indicated as cost-reducing measures on many railroads and will incidentally increase train movement capacity. Length and capacity of trains are, however, not only functions of engine capacity, but are also affected by other equipment of the trains. Outmoded couplers on freight cars may preclude lengthening of trains, and their replacement by automatic couplers may need consideration. Goods movement capacity, moreover, is determined not only by train length, but also by the size and loading of freight cars.

Thus many physical characteristics of rail line and rolling stock affect capacity. In addition, however, operating methods are an important factor. If freight cars are delayed by slow switching operations or are used by shippers and consignees for unduly long periods for storage purposes, the railway's capacity is impaired. The same is true if engines or cars are idle for extended periods because of inefficient maintenance and repair operations. Inadequate ancillary facilities -- such as switching yards, maintenance shops, roundhouses, warehouses and storage sheds, loading and unloading equipment -- may limit a railway's capacity, and their improvement often is the least expensive way to provide the required increase in capacity.

The foregoing description of factors affecting a railway's capacity, although not complete, should be sufficient to suggest the wide range of alternatives to be examined in the PPA. If a full-scale feasibility study is indicated as a result of the PPA, the preliminary appraisal can make a valuable contribution by narrowing the choices and specifying the critical areas to be examined in the more definitive study.

In summary, the purpose of a PPA is to find the particular improvements that are most likely to yield the highest return -- those that will at the lowest possible cost enable the railway to perform adequately that transport service which, in its service area, can be most efficiently provided by rail.

Construction Costs

The costs of railroad construction, of course, vary widely with local topographic and economic conditions, and cost estimates of any particular project must take such variations into account. It may nevertheless be useful to the PPA analyst to compare estimates with an illustrative cost schedule such as that presented in appendix F, table F-1. Although the data in the table are based on U.S. conditions and prices, it may help the analyst to check if any significant cost element has been overlooked. Prices of manufactured items are apt to be higher if they must be imported. Prices of land and labor, on the other hand, should be far lower in LDC's. However, it is emphasized that the pricing of construction must reflect local conditions. Where there is relevant local experience, the unit prices derived therefrom should be used; if pricing modules such as those shown in appendix F must be used, they must be modified by being adjusted to local prices.

While railway projects will often involve some construction or reconstruction -- improvement of horizontal and vertical alignments, double-tracking, replacement of bridges, expansion of marshalling yards or improvement of ancillary facilities -- most projects will involve, as their important component, equipment. As noted, locomotives, rolling stock, communication equipment and rails must be imported in the majority of LDC's.

For this reason, the pricing of these items can generally be based on quoted (or negotiated) prices in major producing countries. This simplifies the valuation of major categories of imports. The appropriate prices are c.i.f. plus local handling (import duties are included in the calculation of the BERR but not the NNRR).

Operating Cost Problems

Properly focused and factually reliable cost data should be available to arrive at meaningful answers to a number of questions of the following types:

- What kind of traffic can the railroad serve on what routes at a lower cost than other modes such as water or road transport?

- Will proposed investments for rehabilitation and improvement make the railroad competitive for the economic life of the proposed investment?

- Will a proposed extension of line or increase in rolling stock attract sufficient traffic and serve it at low enough cost to yield a rate of return on the investment comparable to what could be earned in alternative investment opportunities?

The cost data needed to answer these and similar questions are difficult to obtain for several reasons. Traditionally, railway expense accounts are maintained on the basis of administrative distinctions between separate departments responsible for maintenance of way and structures, signals, and locomotives and cars, and for train operations, station services, etc. The costs of a particular transport service consequently are distributed among all or most of these accounts. Moreover, and regardless of the system of expense accounting, railway operation involves substantial joint costs that are difficult to allocate meaningfully to particular services. It is equally difficult to distinguish between fixed and variable costs.

The most effective method of obtaining the desirable cost information is statistical analysis. A classic example of an analysis, initiated by Canadian railways and extended to U.S. experience, appears in a widely known study, The Economics of Competition in the Transportation Industries.[1/] Unfortunately, this kind of analysis requires great technical skill, and much time and money. Therefore, it cannot be employed generally in a PPA.

Some of the leading concepts of statistical analysis can be employed, however, in analyses of conventional railway accounts to more nearly approximate meaningful cost figures than is otherwise possible. Such analyses will first break up the existing accounts to allocate the expenses recorded in them to operating elements, using such measures of service as train-miles, gross ton-miles, and locomotive-miles or

1/ John R. Meyer et. al. (Cambridge: Harvard University Press, 1959).

locomotive-hours. Most of these allocations can be made by the use of usually available operating statistics, although limited field studies may be needed for the segregation of some of the accounts. Aggregating the costs allocated to each operating element from all relevant administrative accounts yields a total annual cost and subsequently an average unit cost for that element. Further analysis of these cost elements can distinguish terminal and line-haul costs and, to some extent, fixed and variable costs. Appropriate combinations of the results of these analyses can yield rough approximations of the cost data required. Although rough, such estimates are far better than average costs based on global data (e.g., a railroad's total cost per ton-mile of freight and passenger service combined).

The recasting of conventional railway cost data into a form suitable for economic analysis (and project evaluation) should ideally enable the analyst to answer the following types of questions:

- What costs will be incurred in supplying specified services (movement of classes of commodities or passengers) between specified points? The answers will provide guidance in the assessment of alternative modal splits, and in traffic assignment analysis for the railway.

- What reductions in operating costs can be expected from proposed capital investments? Such reductions reflect one of the important sources of benefits from railway projects; if significant, such cost reductions can influence the intermodal split of traffic, perhaps yielding benefits from relief of congestion and excessive maintenance costs on highways.

- Do rates and fares bear a proper relation to the costs of providing the service? The findings here will enable the analyst to assess the likelihood that shippers will, in practice, choose the least-cost mode, other things being equal.

If such an analysis has not preceded the project proposal, the PPA analyst will have to be wary of any operating cost figures submitted.

Traffic and Revenue Estimates

The assessment of a railway's traffic and revenue prospects are closely intertwined. Not only will revenue depend on traffic, but both will depend on the rates charged to shippers and passengers. As pointed out in chapter I, shippers and passengers select the mode of transport they use, among other things, on the basis of the charges they have to pay. The railroad's charges, therefore, should be generally in line with its cost, so that it will retain (and perhaps regain) the traffic for which it is the lowest cost carrier and will not pursue the traffic for which it can compete only at rates below its costs.1/ Appraisal of traffic and revenue prospects, therefore, must be based on at least some review of the rate structure.

Some statistical information on the volume and composition of traffic is collected by most railroads. Usually, however, these statistics are not as detailed as necessary for traffic projection. For this purpose, traffic should be broken down by type of passenger (short-haul and long-haul, by class) and type of commodity, and the origins and destinations of each of these types of traffic should be known. These statistics may have to be compiled from original records generated in the course of daily operations, such as bills of lading and ticket records. If full information on the traffic of at least the most recent year cannot be obtained, a simile of it may be constructed from whatever aggregate statistics have been collected plus a sample study of one or more short periods (selected and adjusted for known seasonal and other variations), station records, and such other supplementary sources as may be available.

Some classification of railway traffic is an indispensable basis for any projections.2/ Estimates of future traffic must

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1/ For traffic that the railway can serve by using transport capacity which it will have to provide in any event or which it can provide at little additional cost, the incremental cost is the proposed yardstick for the setting of rates.

2/ The PPA analyst should beware of conclusions based on aggregate traffic data. To illustrate: At the outset of a 1967 study of the Malayan Railway, its management, the government and

be prepared by applying to each component of the total a growth factor derived from economic analysis of the probable rate of increase (or decline) in the relevant economic activity, with due consideration for probable diversion of traffic from and to the railroad. The prospects of diversion must be discerned from the rate and cost analysis together with the basic trends in modal distribution of transport demand. If rates are in reasonable relation to costs, railways generally can be expected to retain such bulk movements as those of mineral and agricultural products exported in large volume, and of cement, petroleum products and similar cargoes distributed in their service areas. Where a reasonably good road network exists they are not likely to remain competitive with road transport of package goods, especially over short distances. Under these circumstances, they also are likely to lose most of their passenger traffic. These generalizations notwithstanding, local conditions may indicate a less or more favorable outlook for the traffic of a particular railroad, and these local conditions certainly must be taken into account in the appraisal of any traffic estimate.

Assessment of Benefits

The justification of railroad projects has traditionally been made only on the basis of financial analysis: a comparison of the railway's projected revenues with its prospective expenses, including its anticipated capital charges. Since all railroads, including those owned by governments of LDC's, should be expected to operate as profitable enterprises (rather than needing open or hidden subsidies), such a financial analysis remains a necessary part of the PPA. It is not sufficient, however, to justify an investment project.

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the interested public were most concerned about its loss of traffic during the preceding several years and attributed it to service deficiencies and truck competition. In fact, as disclosed by a breakdown of total freight traffic by commodities, gradual loss of large iron-ore movements due to exhaustion of mines was responsible for the sharp decline in total tons carried and total ton-miles, whereas all other traffic (in the aggregate) had increased faster than GNP and faster than road traffic.

As explained in the General Guidelines, the principal test to be applied in the PPA is the return to the national economy. It must be based on real costs and real benefits, viewed from the standpoint of the national economy. The real costs of a railway project usually are not very difficult to measure. They are determined by adjusting the monetary outlays of the railway enterprise to eliminate transfer payments and to replace market prices by shadow prices where this is indicated (General Guidelines, appendix B).

Valuation of real benefits poses more difficult problems (except for railroads serving a single productive development project and justified as part of that project). Because of the wide dispersion of benefits from improved transport service, the benefits that can be measured are mainly the differences in social cost of transport with and without the execution of the project. These differences may arise either from lower costs of handling traffic that would be carried by the railway in any event, or from providing rail service for traffic that otherwise would have to be served at higher cost by road transport (or perhaps even air service).

The estimates of the railway's share in the traffic for which it competes with other modes must be based on the charges payable by shippers and passengers, as has already been pointed out. In contrast, the benefits accruing to this traffic must be estimated on the basis of real costs. Where the railway can serve traffic with existing capacity at small additional cost, the incremental cost is the relevant measure. But traffic that can be served only because of the proposed capital investment has to share the cost of that investment. The cost of serving it must be compared with the cost of the alternative mode of transport. The benefit estimate thus requires knowledge of the cost of road or other transport modes.

Where the railroad enterprise itself (or perhaps another government agency) provides some road transport service and maintains adequate cost records, these records may supply suitable cost data for road transport or at least a basis for cost estimates. Otherwise, road transport cost information may have to be collected in the same way as that for highway projects (chapter III). If trucking business in the area is reasonably competitive, however, it may be justifiable to assume that trucking rates charged to shippers are a fairly good reflection of the trucker's private costs. In this case, they need only

be adjusted to eliminate components which do not qualify as social costs, such as taxes and estimated profits over and above a rate of return adequate to attract the required investment. The opportunity cost of capital (see General Guidelines, appendix B) may be taken as the required rate of return.

In comparing rail and road transport costs, allowance must also be made for differences in service. Unless the rail service is provided from door to door (e.g., from a siding at the point of production to one at the port of shipment or the storage place in the city, or vice versa), the cost of transport to and from the railway station must be included with the rail cost. If there are any ascertainable differences in packing requirements or in damage risks, these also should be taken into account. The cost of slower service for those goods where speed of delivery is of significant value is also a relevant item in the comparison.

In addition to benefits arising from reductions in service costs, railway rehabilitation and improvement projects often are expected to yield reductions in maintenance expense. The recognition of these as project benefits is appropriate in the computation of national economic benefits, but only to the extent to which social costs rather than private railway expenses can be reduced. The railway's saving in maintenance expense may stem largely from the discharge of unskilled labor. Unless these workers are productively employed elsewhere, there is little gain in real benefits, although from the standpoint of the railway's financial costs there is a saving.

Benefits from accident reduction may be more readily measurable on railways than on roads, since the railway is apt to have records of accidents and their effects so that cost estimates can be made. These benefits can be substantial, especially when improvement for safety's sake of accident-prone lines or operations is a purpose of the project.

The Overall Project Appraisal

When best estimates of costs (inputs) and benefits (outputs) have been derived -- or when the accuracy, completeness, and reliability of such data put forward in the project proposal

have been confirmed or modified -- the analyst is in a position to employ the procedures for determination of net rates of return expected from the project. The project should be evaluated from the standpoint of: (1) the railway project as an enterprise, and (2) the railway project's contribution to the national economy. These concepts are distinguished in chapter III, and computations for each are illustrated in chapter VII, of the General Guidelines.

An accurately computed internal rate of return to the national economy, based on adequate data and adjusted accounting prices where appropriate, is the recommended measure on which to base a judgment of the economic merits of the project. However, other (than economic) considerations may enter in at the level of decision-making, e.g., the military advantages or the vulnerability of the project, the government's commitment to the redress of regional imbalances in economic development even at the expense of growth in total national income and product, etc.

Where such noneconomic considerations enter, the quantitative appraisal in terms of an NNRR or a B/C ratio provides a useful means of calling to the attention of the decision-makers the real costs to the economy that are involved in the selection of projects on other than their economic merits.

V. PORT AND WATER TRANSPORT PROJECT APPRAISALS

Introduction

In principle, water transport project appraisals do not differ from those for other transport projects. The PPA should be concerned with the same basic considerations described in the General Guidelines and especially to those applying to all transport modes (chapter I). Still, there are particular factual and conceptual problems which stem from the special characteristics of water transport. These are the subject of this section.

Ocean Shipping

While the development of rail and road transport technologies have sharply narrowed the range of commodities and the areas in which inland and coastal water transport can compete economically, intercontinental cargo traffic is still predominantly waterborne. The only practical alternative -- air transport -- is technically and economically limited to commodities of high value and small bulk for which transport time is critically important, e.g., cut flowers, perishable foods, highly styled apparel, electronic components, etc.

By far the largest part of sea transport is carried out by private and generally competitive enterprises. Even where shipping is conducted by government-owned fleets, such operations are generally conducted by semiautonomous agencies following basically commercial practices.

Yet, whether operated by private or public enterprises, shipping services depend crucially on ports, and these today are almost universally provided by public agencies. They are the object of most PPA's concerned with water transport, and the following discussion is therefore devoted to the appraisal of port projects.

Appraisal of Proposals for Ocean Ports

The growth of sea traffic and the changes in ship technology tend to require improvement of ports almost everywhere. In LDC's, moreover, accelerated economic growth and changes in the structure of the economy often create new and increased transport needs that require improvement of even those ports which were adequate for the traffic of only a few years ago. Finally, many local areas previously served through a more distant port, or through one in a foreign country, desire to have their own port or to attract direct overseas shipping to ports which thus far have been used only for coastal service.

Physical Feasibility

Whatever the reason for the proposal, the first issue to be faced in the PPA is the suitability of the physical characteristics of the location of the port project. Development of a new port or upgrading of a small existing port to a full-scale ocean port will result in wasteful capital investment if the location does not permit satisfactory operation, attract a sufficient volume of ship traffic, and leave room for future expansion. A considerable variety of physical and economic factors require attention. Among these are

- The depth of water in approach channels and at the site of the proposed wharves

- The amount of dredging necessary to establish and maintain the required depths, based on the anticipated types and sizes of vessels that will use the port, and known or estimated rates of siltation

- Hydrographic and meteorological conditions -- currents, rainfall, wind velocities and prevailing directions, and other factors affecting movement of vessels on and off the berths, handling of cargo, protection of cargo, etc.

- Topographic conditions onshore and offshore, as they relate to land transport links, storage facilities, ease of access to the port, and protection of vessels from storms while in port.

Most LDC's can justify only one or a few general cargo ports. It is essential, therefore, that port location be carefully examined so that ports will be located where construction and maintenance costs can be minimized and interconnections with land transport modes can be made efficiently. Alternative locations should be considered, even for proposals put forward to expand or improve existing facilities.

Proposals to upgrade local ports -- used in coastal shipping or as home ports for fishing fleets -- must be examined with a critical eye not only with regard to the natural constraints, but also with regard to the suitability of the location with respect to the land transport network, to major ocean shipping routes and to the traffic generating centers in the country. While the lack of an ocean port may impose a critical constraint on development, provision of a port does not guarantee a more rapid rate of development in its hinterland.

The Role of the Port in the Transport System

The hinterland, or service area of a port, is that region or area which receives its imports and dispatches its exports through the port. The limits of the area are set, in general, by the total private costs of transport between the port and inland origins (for exports) and destinations (for imports), relative to the costs to and from alternative ports.

Projects to improve the operation of a port require evaluation regarding the effect of the proposed improvement on the transport network in which the port is a link. If, for example, the critical constraint on movement through the port is in the road and/or rail links of this network, a capital investment to improve port operations will yield greater benefits if accompanied by improvements in the more critical links of the network, i.e., highways, road and/or rail transport.

Even more crucial than the interaction between port and land transport operations is the influence of port service on the cost of sea transport. Except for fuel consumption, virtually all the costs of ship operation are the same for a day in port as for a day at sea, and the added cost of loading and unloading is a high proportion of the total cost for most general cargo. That total cost, therefore, is sharply raised

when the ship must wait until a berth becomes available or is delayed in port by slow loading. Moreover, cost-reducing application of modern ship technology involves high capital investment which can be made to pay off only if the share of voyage time spent in port is limited; hence, the less efficient the ports on a trade route, the less likely is the introduction of modern, cost-saving vessels by the ship operators.

Estimation of Capacity Requirements

The basic steps in estimating the capacity requirements for a port are not essentially different from those used for other transport facilities. There are, however, factors that complicate the translation of estimated tonnages into physical requirements (number, size and types of berths, storage and transit sheds, and handling equipment). These complications arise, in part, because of the uncertain spread of containerization the rapidity with which ship size is increasing, and the possible use of LASH vessels, as well as the differences in types of general cargo, the balance or lack thereof between imports and export tonnages, the quantities of cargo loaded and/or offloaded per vessel, and other factors.

The following factors should be examined, in roughly the order noted, in the estimation of the required capacity:

- The hinterland of the port should be established, based on the existing or proposed land transport network, relative costs of land transport, and the location of alternative land-sea links.

- Traffic generating economic activity in the hinterland should be projected by major commodities for export, and the demand for imports by type of goods should be estimated. Some historical data on exports and imports will generally be available, although these will require supplementation by other information in the projections, e.g., government policies to restrict imports and/or encourage exports, the projected rate of growth in income and population in conjunction with "propensity to import," and planned structural changes in the economy of the hinterland.

. Total annual projected tonnages should be broken down to reflect irregular movements through the port attributable to seasonal variations in production or demand, irregular calls by vessels, land transport bottlenecks, and predictable weather patterns (such as monsoons) that may disrupt the even flow of goods through the port.

. Given projected annual tonnages and at least a rough estimate of seasonal peaks, the next step is to translate the traffic into physical facilities required. As suggested above, this is a difficult and complex undertaking. No complete list of specific factors to be provided will be applicable in all appraisals, but the following are among the variables to be considered:

-- Type of major commodities. Bulk commodities (e.g., grain, ores, coal, POL, fertilizers, cement) require different and preferably separate port facilities than those suitable for general cargo.

-- Size, frequency of call and loading and unloading equipment on shore and on vessels.

-- Typical tonnage per shipment.

-- Working days per year and shifts per day.

-- Efficiency of port management and longshoremen.

-- Customs procedures for clearance of imports and exports.

-- Availability and utilization of lighters for loading and discharge of cargo to private jetties.

-- Containerized (and pelletized) cargo as percentages of the total.

The influence of these and other variables on the number, size and types of berths, storage space and other onshore facilities must be assessed. In the absence of more specific information, an estimate of 1.0 to 1.2 tons of general per linear foot of wharf per day can be used to arrive at a rough measure of required capacity with no containerization.1/

There is obvious need for port improvement when berth capacity is no longer sufficient to accommodate ships promptly, and even more need when growing transport demand indicates that more ship calls will be made and port capacity must be increased to forestall costly ship delays. It does not necessarily follow, however, that the increase in capacity must be achieved by providing more berthing space. Frequently, improvements in port operations are a realistic alternative to heavy capital outlays for expanded physical facilities.

Cargo handling can be accelerated in a variety of ways. Mechanical handling equipment may pay off by saving ship time even where the labor cost of manual handling is low. Adequate and uncluttered space for moving cargo and vehicles at shipside, in transit sheds, and throughout the port area also can accelerate cargo operations; the spatial organization of the entire port area therefore deserves as much attention as the berth capacity.2/ In most LDC's, moreover, the least expensive way to increase port capacity is the introduction (where it is not already in use) of a second and, at least during peak periods of traffic, a third shift, even though shift premiums will have to be paid.

The PPA for a port project thus has to pay attention to many operational aspects, not merely to proposed construction. All of these aspects need to be considered in the light of the special network role of the port in the transport system, its function as a link between sea and land transport. The

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1/ Robert R. Nathan Associates, Inc., and Frederic R. Harris, Inc., op. cit., Vol. 4, annex D, p. 105.

2/ Special loading and unloading facilities for both dry and liquid bulk cargo should, if at all possible, be located away from general cargo ports, especially if the industrial plants dispatching or receiving the bulk shipments (e.g., petroleum refineries, cement factories, power plants, flour or sugar mills, etc.) can be erected elsewhere at tidewater.

tradeoffs in terms of discounted values of costs and benefits can be evaluated by means of the techniques described in chapter IV of the General Guidelines.

The Special Case of Container Operation

Provision of port facilities to accommodate container service requires large capital investments and a lead time of several years. Since it may affect the layout of the entire port area (or an important section of a large port), there is a strong tendency to include preparation for container service in almost every port improvement project. Yet there still is great uncertainty as to when, if ever, container service will actually reach many of the ports in LDC's, what form it will take, and how much cargo it will move. No definite guidelines for decisions on container service can be provided at the present time.

Certainly, some years will pass before the probability of one or another kind of container service to many ports in LDC's can confidently be estimated. The very costly port facilities needed for full-fledged container service may never be used at many of these ports. These facilities include large wharves with special lifting gear and high bearing capacity for the vehicles carrying large and heavy containers to and from shipside, plus sufficient backup area with the same bearing capacity for maneuver, as well as storage sheds where containers can be stuffed and broken up. Less costly facilities are needed for more limited occasional container service, especially if only smaller containers are used.[1/] Stage construction also may be employed to provide for all possible future needs while reducing, at least to some degree, immediate capital investment.[2/]

Pricing Port Projects: Inputs

The costs of construction for new ports, or additions and improvements to existing ports, will require some engineering evaluations to determine such quantities as:

1/ Virtually all containers are 8 feet wide and high, but their length ranges from 10 feet to 34 feet and their weight varies correspondingly.

2/ The Port of Penang in Malaysia, for example, included

- The volume (and composition) of dredging, and the nature of any work required to clear approach channels

- Depth and quantity of piling, and the nature of the subsurface strata

- Amount of fill, grading and land preparation required for the port area

- Number and size of transit sheds, storage buildings and other structures

- Estimated quantities of materials for wharves, roads, and other surfaced areas.

The unit prices applied to these physical inputs should be based insofar as possible on local experience. In the absence of such data, prices in other countries can be used, with adjustments to reflect local conditions insofar as data permit. Since most of the equipment and some of the materials used in port construction will be imported, c.i.f. prices will be appropriate for application to a substantial part of total inputs.

Economic Assessments of Port Projects

Port projects have traditionally been justified by a purely financial analysis in which prospective costs were compared with estimated revenues of the port agency. This is not an entirely satisfactory economic justification, even if port revenues are reasonably related to the benefits accruing to port users. In fact, the complex schedules of charges to ship owners, shippers, consignees, and other incidental users of port facilities almost everywhere are products of history, modified from time to time but poorly related either to the benefits of port users or to the costs of the port agencies.

The principles of economic assessment of port projects require a better measure of benefits to the national economy.

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construction of a container berth in its improvement program but postponed the provision of heavy lifting cranes.

The principal purposes of port improvement are to facilitate maritime service and to reduce its cost by making cargo handling more efficient and by shortening the time ships must spend in port. It is not difficult to measure the time saved by ships when port improvement eliminates a need to wait for a berth or to wait for the proper time to enter a port with limited access. The efficiency of cargo handling and the value of ship's time, however, depend on the design of the ship (the speed, the number and location of hatches, the arrangement of decks, etc.) and many elements of the voyage schedule, such as the distance between terminals, the number of intermediate ports and the circuity involved in reaching them, the volume of cargo available in both directions at each port, the nature of the cargo and the consequent revenue per unit of weight and space.

The most practical measure of port improvement benefits to ship operation is that based on the assumption that there will be no change in ship type or voyage pattern and that the port time saved can actually be used to speed the entire voyage correspondingly and to reduce operating costs by the appropriate multiple of daily ship's cost.

In estimating the saving in ship time, the PPA analyst will have to recall that benefits are to be measured with and without execution of the project. Consequently, the ship time saved will be the difference of port time needed to handle the cargo volume expected in each future year under consideration when the total number of ship calls is apt to be larger because of growing traffic demand and when waiting time per call is apt to be increased if port capacity is not enlarged. Demurrage charges which can be avoided with the project, but which can be expected to increase without it, are a major benefit of projects to reduce congestion. The benefit estimate, of course, will also take account of any effect of the port improvement on the cost of cargo handling and the cost of inland transport, if such effects can be confidently anticipated. In addition, any clearly expectable savings of the port agency in operation and maintenance of port facilities will have to be considered.

This method of estimating benefits presupposes that savings accruing to ship operators will be passed on to the national economy. The validity of this assumption is clouded by several characteristics of the general cargo shipping

business.[1] Most general cargo moves in cargo liners, and the operators of these ships on most trade routes are organized in liner conferences. Although the restraint on competition exercised by such conferences is not as strong as may appear at first glance, the adjustment of conference rates to savings in a given port will not be forced by actual competition unless the port is also served by independent operators (on each of its major trade routes if there are several). If this is not the case, pressure from interested shippers and government agencies may achieve the reflection of cost savings in freight reductions, especially if both the available cargo volume and the savings due to port improvement are large enough to suggest the possibility of new service by conference outsiders. Until freight reductions are achieved, however, most of the benefits from port improvement will be captured by the ship owners, who are apt to be mainly foreign interests. The national economy then will benefit only to the extent to which the higher profitability of ship operation increases the ship owners' interest in providing good service at the port.[2]

Rates of Return and Evaluation Summary

Internal rates of return, or B/C ratios, should be computed from both the enterprise (port authority) and national economy points of view. Accounting or shadow pricing should be employed in the circumstances described in the General Guidelines in the computations designed to assess the project's benefits to the national economy. The wide range of measures available to increase effective port capacity -- some of which require heavy investment, while others do not -- will make the particular measure that is recommended sensitive to capital cost and availability.

1/ Although tankers carry approximately half of all maritime freight and other bulk carriers about half of the remainder, they are disregarded here because these guidelines deal only with the appraisal of investments in public transport facilities, and bulk carriers are usually served by private installations, especially in LDC's.

2/ Some possibilities may exist for adjustments in port charges in such a way as to increase the share of benefits from port improvements accruing to the national economy.

Suggested forms for the rate of return analysis and topical outlines are shown in chapter VII of the General Guidelines.

Inland and Coastal Water Transport

Inland and coastal water transport now tend to be of limited and declining importance. Nonetheless, inland and coastal water transport continue to play an important role in the transport networks of more, as well as of less, developed countries. Although the vessels engaged in this form of transport are not generally the object of projects involving the public sector, works to improve and maintain facilities for inland water transport (e.g., dams, locks and navigational aids) may be provided at public expense. In some respects, the economic and financial considerations involved are analogous to those arising in highway appraisals, for in both, the government provides facilities that are used by predominantly private carriers. Thus, user charges may be applied to recover -- at least in part -- the costs of providing such facilities.

Water transport on rivers or lakes and along ocean coasts is still the principal means of transportation for people and goods in areas where road construction is extremely expensive because of topographic conditions or is uneconomic because of low population density and productivity. It merits at least an exploratory consideration by the analyst, for it may well be the most efficient means of providing better transport service for an area where an unduly expensive road project is proposed. Motorized craft suited to the particular physical conditions and traffic needs may provide a satisfactory solution and may require far less capital than a road.

Inland and coastal water movement also remains an economic mode of transport for liquid and dry bulk cargoes, even in areas where road or rail service is available and even in highly developed countries. Such bulk movements usually are private or quasigovernmental operations of the enterprises concerned with the goods (petroleum, mining, cement companies, marketing boards for agricultural products, etc.). While the craft engaged are generally privately owned, government expenditures on maintenance of waterway facilities may be involved. In any case this mode should be considered as a possible alternative when

road and rail projects are analyzed that might compete for the same traffic. Where water movement can be used from origin to destination, and where speed of movement and perishability are not important considerations, the lower cost usually attracts the traffic.[1/]

In the eval ation of inland and coastal water transport, it is generally possible to restrict the analysis of benefits to those associated with the movement of a fairly narrow range of (bulk) commodities between a limited number of origin and destination points.

1/ Coastal shipping of general cargo may perhaps also be revived in some areas if container service is divided into long-haul operations between major ports and short-haul service between major and satellite ports. See the section on container operation.

VI. AIR TRANSPORT

Introduction

This section contains brief discussions of major factors to be considered in PPA's for: (1) airports, including ancillary facilities, and (2) aircraft. While air transport accounts for a relatively small fraction of total passenger-miles and ton-miles of cargo traffic, it is the most rapidly growing form of transport, and therefore a relatively large number of projects are proposed in this area.

Airports

The physical requirements for airports are largely determined by the number, size and operating characteristics of the aircraft using the facility; the number of passengers and cargo tonnages; and the range of ground services offered by the airport.

The first step in the appraisal of an airport project is the assessing of the suitability of the proposed site. The principal factors to be considered are:

1. Characteristics of the terrain and size of area available. Airports require comparatively large areas of reasonably flat land, and a larger area free of high obstructions, natural or man-made. Soil requirements for runways, taxiways, and aprons are essentially the same as for heavy-duty highways. The area should be free of serious drainage problems and should provide adequate space for passenger and cargo terminals, service facilities, restaurants, shopping and parking. The total area required must be determined on the basis of traffic forecasts.

2. Location. A compromise is usually required in the choice of location. Although it is desirable that airports be located close to the population centers they are to serve in order to minimize travel time and distance from the airport to origin and destination, other factors must also be considered, including:

a. Heavily populated areas, which must be avoided in approach and climb-out areas

b. The location of other airports and their approaches, which is likely to be of less importance in LDC's than in highly developed countries

c. Pollution, noise and air

d. The cost of land, which is likely to be more expensive in areas close to cities

3. Airspace requirements.

As the size of planes and noise levels increase, airports tend to be located at a greater distance from the centers they serve.

3. Access. Ease of access for motor vehicles must be readily available or must be provided in conjunction with the airport project.

4. Zoning. To prevent encroachment on future space required for expansion, and to prevent the erection of structures that impair approaches, it is important that the areas surrounding the airport be zoned.

5. Length of runways and bearing strength. These must be determined on the basis of the characteristics of the aircraft expected to use the facility, the elevation, the length of the longest nonstop flight of planes taking off from the airport, and climatic and weather conditions. Standard runway requirements under varying conditions are available for most aircraft.

6. Navigation and communication equipment. Requirements for these facilities will again depend on the type of aircraft and the projected number of takeoffs and landings per hour during average peak periods, and under IFR conditions. If the airport is to serve traffic at night, the requirements will be higher than if it operates only during daylight hours. Also, if the airport is to serve major international routes, navigation and communication requirements will have to meet standards for this type of service.

In most LDC's there will be only one or perhaps two international airports. Other airports in these countries may range from the cleared-strip class to fully developed airports capable of accommodating small and medium-sized jet craft.

Projecting Demand

Air transport is the fastest and generally most expensive form of transport. Its use, even though subsidized, is therefore restricted to a relatively small segment of the population for whom time is valuable and for whom the higher cost of air travel is permitted by their relatively high incomes. Cargo transport by air is usually restricted to commodities having high value in small bulk and/or requiring speedy transport because of their perishable nature, e.g., cut flowers, style goods, seafood, electronic components.

These characteristics do not, at first glance, suggest a high level of demand for air service within LDC's or to and from other countries. Nonetheless, air transport is important in many LDC's for both objective and subjective reasons.

The fact that the amount of time saved by air transport increases with distance and with the degree of difficulty encountered by ground transport may justify, on objective grounds, the use of such transport in LDC's. Travel to areas that are remote either because of distance or difficulty of access may, as a practical matter, depend largely on air transport. Subjectively, air service is valued highly as a symbol of progress and of status in the community of nations.

Both physical and socioeconomic factors need to be considered in projecting the demand for air transport. The assessment of these factors is facilitated if it is remembered that the value of time saving must justify the high cost of air service. It follows that, other things being equal, internal air service is more useful in a large territory than in a small one. If the more densely settled regions within a large territory are separated by thinly populated areas, air service may in fact satisfy a transport demand at a lower total cost than would road or rail service, which would require large investments to carry it through long stretches where there would be no local traffic.

The same advantage of air service may be present even in a territory that is not very large if settled areas are separated by topographic conditions that make road construction inordinately expensive or unrewarding: Large virgin forests, high mountains, deserts, extensive bodies of water or swamps may create conditions under which the use of air transport is indicated even for relatively short distances. Where no such conditions prevail, short-haul air transport is not likely to be cost-competitive once reasonably good road transport becomes available.

In projecting future demand for air transport, it is useful to develop separate estimates for each of the following components, as each is likely to be influenced by different growth determinants in LDC's:

- Commercial passenger traffic:
  - -- Government officials
  - -- Businessmen
  - -- Individuals, normally in the upper income brackets, traveling for personal reasons
  - -- Tourists, local and international

- Cargo traffic, by major categories of commodities or industries served

- Demands by owners of private aircraft, used for pleasure or business

- Military requirements as they affect joint civilian-military facilities.

The first and second of these components will be relevant for the appraisal of proposed aircraft acquisitions, as well as for airport projects; the third and fourth components of demand are relevant only in the appraisal of airport projects.

Projections of demand by the various types of passengers should be based on:

- Projected increases in personal incomes

- Anticipated growth in the nonagricultural sectors of the economy, by service areas

- Assessment of the country's potential for tourism, both as a destination point and as a stop-over for regional destination points. These factors can influence the demand for domestic as well as international air service

- Government policy with respect to official air travel.

In projecting levels of future demand for domestic air transport it is important to assess -- insofar as possible -- the pent-up demand, that is, the extent to which present use of air transport is limited by the available capacity of planes, or by the lack of airports in potentially lucrative origin and destination points.

Where some data on domestic traffic between existing airports are available, the potential traffic on proposed routes may be estimated by use of the "gravity model" explained in appendix B. Although this technique was developed to estimate interzonal trips by road, it can also be applied for air travel, with appropriate modification of the coefficients.

Given estimates of the number of passengers and cargo tonnage enplaning and deplaning at each airport, the estimates must be converted into plane arrivals and departures. The conversion will require forecasts of seat capacities of planes to be used, load factors and frequency of service. These projections must obviously be made in conjunction with the planned composition of the aircraft fleet.

Pricing of Airport Projects

The pricing of airport projects presents no special problems; the procedures -- modular pricing adjusted for local price differentials, shadow pricing where appropriate, and separation of foreign exchange and local currency costs -- described in the General Guidelines are also applicable to airport projects. Major components for which order-of-magnitude cost estimates are to be prepared include:

- Land acquisition costs or annual rental value and costs of site preparation

- Engineering and design costs, usually involving a heavy foreign exchange component
- Runways, taxiways and aprons
- Access roads, driveways and parking areas
- Hangars, aircraft service buildings, fire and rescue facilities
- Passenger and cargo terminals, including space for restaurants, shops, customs facilities and possibly hotels
- Utilities: water, telephone, electric power, sewerage and drainage
- Fuel storage and service facilities
- Fencing, landscaping, blast protection
- Communication and navigation equipment

Measurement of Benefits

The time saved by passengers, and the shippers and consignees of air freight, constitutes the source of the benefits of air transport. A meaningful valuation of these benefits in a form suitable for use in computation of standard measures of economic feasibility is extremely difficult, particularly in LDC's.

The prospects for the computation of a meaningful measure of financial feasibility are somewhat more promising. Airports, at least major ones, are usually operated by semiautonomous bodies, so that expenditures and receipts attributable to its operations are identifiable. Major sources of revenues include:

- Landing fees, servicing charges, storage charges and other receipts from airlines
- Airport exit "taxes" paid by passengers
- Admission fees to observation decks paid by airport visitors

- Rental receipts from concessionaires occupying terminal facilities

- Income from use of land areas reserved for future expansion

- Government subsidies.

Although the ultimate benefits of the time saved by air travel are difficult to value, the monetary costs of delays to aircraft operators and passengers have been computed for airports in the New York area. These are shown in table 4.

Table 4. Estimated Cost of Delays to Aircraft Owners and Passengers

(dollars per minute)

Delays	Kennedy Airport	LaGuardia Airport	Newark Airport
Commercial carrier arrivals..	$14.13	$11.18	$10.24
Commercial carrier departures	9.38	7.28	6.34
General aviation arrivals....	1.30	1.36	1.38
General aviation departures..	.80	.86	.88

Source: A. Carlin and R.E. Park, The Efficient Use of Airport Runway Capacity in a Time of Scarcity (Santa Monica, California: The Rand Corporation, 1969), Table D14, p.206.

As congestion develops or is anticipated, the appraisal of projects to expand airport capacity can be appraised in terms of savings in time (due to reduced delays) and thus in terms of reduced costs. The techniques useful in the estimation of the value of these savings are essentially the same as for road transport and for the reduction of delays for vessels in ocean ports.

Two elements are involved: the value of the reduction in aircraft operating time, including the cost of the crew,

fuel, and lost bookings attributable to delays; and the value of time lost by passengers. As suggested in connection with the measurement of the value of time in road transport, restraint should be exercised in placing a value on passenger time saved by the avoidance of delays.

The establishment of a new airport may also require assessment in terms of its role in the general economic development of a region or service area. Suggestions made elsewhere in these guidelines are relevant in such cases.

Selection of Aircraft

Once the general magnitude of prospective traffic has been estimated, the appropriate type of service must be matched to it. The volume of traffic that can be handled depends on two factors: the size of the aircraft employed and the frequency of trips made. Generally, the larger and faster the aircraft, the lower is its cost per available seat-mile. However, the cost per passenger-mile depends heavily on the proportion of potentially available seat-miles actually utilized; that is, on the ratio of actual to potential aircraft service time and on the ratio of occupied to available seats (the load factor).

As a result, few internal routes in LDC's justify the employment of even the smallest of the modern jet aircraft. These aircraft have the lowest cost per available seat-mile, but they provide far more seat-miles per day than the traffic is likely to utilize. Capability of airports to handle jet aircraft is also a constraint.

Although the more heavily traveled internal routes will require the use of turboprop equipment (available in various sizes), still smaller and slower propeller planes (also available in various sizes) will suffice where prospective traffic volume is light, important as it may be. In assessing the characteristics of different types of aircraft, it is necessary to recognize that the cost of necessary ground facilities rises when larger and faster aircraft are employed. Although smaller planes are slower, their speed advantage over ground transport is still large, especially where the need for air service is due to difficult ground conditions rather than to long distance.

In the design of the operating pattern, the frequency of service and aircraft routing must be paired with the chosen type of equipment. Where a very low volume of traffic is anticipated, service on demand (such as taxi service) may be the best solution. At a somewhat higher traffic volume, a few trips per week rather than several per day may be scheduled, and the equipment may also be employed on several adjoining or neighboring routes. Even if traffic justifies service once a day or still more frequently, it may also be necessary to use the same aircraft on more than one route to obtain satisfactory equipment utilization.

To assure dependable service, more than one available aircraft is necessary. Preferably, a spare should be available for use whenever an aircraft is out of service, although the cost looms large if the active fleet consists of only one or two planes. Service dependability also requires purchase of a spare-parts supply at the outset, as well as its regular maintenance. Postponement of the purchase of spare parts until they are urgently needed may save initial investment cost, but it is apt to prove very expensive in the course of operation.

Provision also must be made for regular maintenance and overhaul. Whether these activities need to be conducted by the carrier itself depends on the availability and costs of alternatives. Facilities for major maintenance require sizable investment. A small carrier will do better to have its equipment maintained by a larger airline, by a facility established jointly by several neighboring carriers, or by the facilities of a manufacturer, if any of these is available within manageable distance and is equipped to handle aircraft of the chosen type. The cost importance of such arrangements makes it necessary to consider them in advance when the aircraft type to be used is selected.

Engineering estimates of the cost involved in any particular equipment and service pattern are not difficult to secure. They should include, of course, the cost of ground facilities that need to be provided for the proposed service. Attention needs to be paid to the fact that much of the cost of any air service in a less developed country must be paid in foreign exchange. Equipment of all kinds must be imported; in most countries fuel must also be imported. In addition, foreign staff is likely to be employed in a variety of capacities, and

domestic personnel capable of filling managerial and technical positions, including those of skilled workers, may require training abroad. In any event such personnel are among the country's scarce resources for which a shadow price may be a more appropriate valuation than the wages and salaries they are expected to receive.

Once an estimate of the total cost has been provided for any given equipment and service pattern, the resulting transport cost per unit of expected traffic can be readily computed. The PPA analyst may, however, require more than one such set of estimates if more than minimal traffic is expected. Since there may be some elasticity of demand and since the cost of service depends on the volume offered, demand and supply may be matched at more than one level. Some government subsidy may be required in any event, but it is not necessarily lowest at the most modest level of service.

The PPA can be made more useful to decision-makers if it includes a set of (discounted) costs corresponding to each of several service levels. Such service levels may be described in terms of the number of terminal points to be served, the frequency of service, the speed of service, etc. Alternative combinations of inputs to provide specified levels of service should be examined to determine the least-cost combination (General Guidelines, chapter IV).

APPENDIX A. PRINCIPAL CHARACTERISTICS OF TYPES OF TERRAINS AND SOILS

Different surface and subsurface conditions are associated with each general type of terrain: the alluvial plain, the terrace, the bedrock plain, the hill and mountain. Because less developed areas embrace a wide variety of terrain types, a brief analysis of the suitability of the general terrain types for road location should be helpful to the PPA analyst.

Alluvial Valleys and Coastal and Interior Alluvial Plains

Alluvial valleys and coastal and interior alluvial plains contain extensive flat land and require little or no grading. When grading is required, the ground is usually soft and easily excavated. Because of differences in deposition and source of the alluvial material, the more suitable areas having better drainage and coarser soil can be expected at the margins of plains where alluvial fans spread out from the foot of bordering hills and mountains, along streams which are bordered by natural levees, and along the coast on dunes and sandy beach ridges.

Some plains areas are poorly drained and underlain by fine, silty, or clayey soils which are hard to stabilize and may be subject to heaving during freezing weather. Their water table is generally high, and flooding possibilities should always be considered. Obviously, swamps, bogs, and marshes are to be avoided if possible; they involve an expense of time and labor not feasible for most road projects.

Streams and beaches may be sources of sand and gravel for construction if suitable nearby rock has provided source material to the streams or waves. Usually, river gravel is most abundant in stream beds close to hills or mountains of hard rock, but is practically nonexistent in the deltas at the outer edges of wide plains. Beaches on coral islands are composed largely of coral sand, not of common quartz sand which is usually lacking. Water is usually obtainable from nearby streams or lakes, except in arid regions. Ground water is also usually obtainable in alluvial plains without difficulty.

Natural Levees

The natural levees of large streams may provide acceptable road sites, except where flood conditions are prevalent or extensive. Their soils are composed of coarser materials and are normally better drained than those of the lower land on the adjoining flood plain. The sand composing the levees may be too fine and silty to have bearing power, although it is usually better in this respect than the soil of the surrounding area. Alignment of highways is necessarily limited to the direction of elongation of the levees, and fill might be required to widen the levee. Fill is not practicable where streams are actively cutting into their banks, except for temporary installations.

Alluvial and Marine Terraces

The flat areas which in places border alluvial plains, continental coastlines, or islands can sometimes provide excellent sites for road construction. Since their surfaces are above the adjacent stream, lake, or ocean level, they are generally well drained and free from the danger of floods. In alluvial terraces, the water table is normally low and drainage is generally easy to establish where natural drainage is not sufficient. Depth of the bedrock varies with the type of terrace. The main objection to terraces as road sites is the frequent presence of steep-walled valleys and ravines, which occasionally are so closely spaced that they cut the surface into small segments. Gravel and sand deposits suitable for use as construction material underlie many terraces and are usually obtainable from bordering escarpments or ravine walls. Hard rock may also be exposed in cuts or in nearby hills and mountains.

Bedrock Plains and Plateaus

High-level bedrock plains or plateaus, underlain by flat-lying rocks or developed by erosion on folded or massive rocks, may be superior to adjacent lowlands as road sites, especially where the lowlands are poorly drained or offer poor foundations. However, the flat plateau surfaces may be intricately dissected by ravines or may contain minor relief irregularities,

such as the scabland type of topography on lava plateaus and the sinkholes and pinnacles on some limestone-capped plateaus. In such cases, grading generally requires rock excavation. The high surfaces are naturally well drained, and if they are not, good drainage can easily be established. Foundations are generally good.

The residual soil cover on bedrock plains may vary considerably in thickness and character, depending on the underlying rocks, the age and geologic history of the plateau, and the climatic conditions. On recent lava flows, the residual soil may be very thin or entirely lacking. In other places, particularly in the tropics, the mantle may be so thick that grading does not reach bedrock and the finished foundation is on the soft, residual material. The bedrock under plateaus and high plains may also be covered by thick deposits of transported materials such as falls of ash or coarser fragments ejected from volcanoes, loess, dune sand, stream-distributed gravel and sand, and glacial drift. Such foundations vary greatly as to suitability. Some consist of well-drained coarse soils, such as the fragmental igneous rock soils and sand dunes and the sandy, residual soils developed on granites. Other foundations have poorly drained, fine soils, such as the clayey soils developed in place on such rocks as limestone and shale, and the plastic, clayey soils found in some areas of glacial drift. Loess and other silty materials, when undrained because of underlying impervious beds, may be subject to frost heave.

Rock suitable for construction is usually abundant on bedrock plains and plateaus; sand and gravel are usually locally available. The distribution and amount of surface and ground water available are highly irregular.

APPENDIX B. SUGGESTED TECHNIQUES FOR ESTIMATING TRAFFIC VOLUME AND DISTRIBUTION

Where information on traffic volumes for a sizable number of past years is unavailable, more generalized projections of future traffic can be developed by the use of partial information.

Bases for Traffic Projections

The following sources may be used as bases for traffic projections:

- Growth of traffic in another region in the same country with a previously completed, similar transport project

- Rates of increase in traffic in one or more (preferably neighboring) countries at similar stages of economic development

- Statistics reflecting the growth of relevant components of the country's gross domestic product (for example, the rate of increase in traffic involving movement of agricultural exports to ports may be projected on the basis of anticipated growth in production of these commodities)

- Census figures showing population growth

- Annual increases in vehicle registration

- Annual increases in national road mileage

- Annual increases in highway fuel consumption.

These sources may be examined for correlation with traffic growth in the service area on the basis of past performance. In forecasting, it will be helpful to establish the range of estimates for high, medium, and low growth rates. For longer term projections, the governmental goals and policies relating to regional land use and development should be considered.

In translating market demand into traffic estimates, the basic parameters are measured in terms of the following volumes:

- Annual traffic (vehicles per year)
- Monthly traffic (vehicles per month)
- Average daily traffic (ADT) (vehicles per day)
- Peak hourly traffic (PHT) (vehicles per hour)

Annual traffic is the total number of vehicles expected to use the highway in 1 year, and is used for determining annual travel, estimating expected highway user revenues, and indicating trends in volume, especially on toll facilities.

Average daily traffic (ADT) is the general unit of measure used in reporting traffic on a highway and is the annual average daily traffic. It represents the total traffic for the year divided by 365. ADT is helpful in determining the demand for service by the highway, evaluating the traffic flow with respect to the overall highway network, developing the overall highway network, and identifying localities where new facilities or improvements to existing facilities are necessary.

Peak hourly traffic (PHT) is used for determining length and magnitude of peak periods, evaluating road deficiencies, and establishing traffic controls and the geometric design of roads and intersections.

Composition of Traffic

Traffic composition can generally be classified into four categories:

- Trucks
- Passenger vehicles
- Motorcycles
- Bicycles

For purposes of general studies, it is customary to consider the traffic mix to consist of trucks and passenger vehicles, with motorcycles being classified as passenger vehicles. Light delivery trucks such as panel or pickup trucks may also

be classified as passenger vehicles. All buses, single-unit trucks, truck combinations, vehicles weighing 9,000 pounds or more, or vehicles having dual tires on the rear axle can be considered trucks.

Truck traffic is expressed as the percentage of total traffic during the design hourly volume. Most trucks operate steadily throughout the day, with the result that the truck peak seldom coincides with the passenger-car peak. For general estimates, the customary procedure is to consider truck traffic to be 15 percent of ADT in the absence of specific data indicating a different composition.

Special Components of Traffic

In an evaluation of traffic projections for industrial, commercial, or agricultural developments, production rates can be translated into highway traffic volumes by the estimating of the type and capacity of the transport vehicle. If consideration is given to the seasonal characteristics of the production facility (such as crop harvest), annual, monthly, and daily traffic volumes can be projected. These volumes can be superimposed on a traffic chart along with other estimated traffic volumes to arrive at total traffic for the route segment. This chart usually is presented with the months of the year as the ordinate and the monthly percent of annual traffic as the abscissa. In this way traffic is displayed as a function of time and variations from the average are readily distinguishable.

Distribution of Traffic

The generation, distribution, and assignment of traffic are basic to traffic estimation. From studies previously mentioned (O/D, statistical analyses of GNP data, similarity comparisons within and between countries), an idea of the amount of traffic that might be generated can be developed by due consideration of the specific uses of lands being served by the highway project. Some land-use centers that generate traffic are residential areas, business districts, commercial areas, and agricultural areas.

To distribute the estimated traffic, the simplest mathematical method that may be used is the gravity model.1/ The gravity model is based on the theory that traffic generating areas attract traffic to them in proportion to their own size (in terms of population or economic factors) and inversely in proportion to the square of the distance between them.

The basic gravity formula is given as follows:

$$T_{1-2} = \frac{KP_1 . P_2}{d^x}$$

Where T_{1-2} = number of trips between areas 1 and 2

P_1 = population of area 1

P_2 = population of area 2

d = distance between areas 1 and 2

x = some power of d, frequently 2

K = A constant used to adjust the different dimensions used in the formula and to weight the attractiveness of the area.

Another method for estimating future traffic distribution between zones is based on the assumption that future distribution will be similar to present distribution and will be influenced mainly by zone size. Future trips generated in each zone are computed by multiplying present trips by a growth factor based on statistical studies, and trips are then distributed among zones in accordance with the attractiveness of each zone.

The step requiring the most judgment in traffic planning is the assigning of the estimated traffic to alternative modes and routes between pairs of zones. No generally accepted method has been developed for assigning trips to alternate modes of transportation. This is highly dependent on local existing

1/ Because the development often entails a break with the past, mathematical relationships based on past data should be used with caution. This is particularly true where transport facilities open up new areas.

transport facilities and access to them. In the assigning of trips to specific alternative highway routes between origins and destinations, both travel times and travel distances can be used as criteria in selecting the preferred route.

APPENDIX C. DESIGN CHARACTERISTICS AND CAPACITY: INTERURBAN ROADS AND URBAN STREETS IN LDC's

The number of vehicles that a road or street can accommodate at specified running speeds will depend on the terrain, the physical characteristics of the road (running surface, shoulders, horizontal and vertical alignments and sight distances) and the composition of the traffic, especially the proportion of the traffic accounted for by heavy vehicles.

The relation of these variables is shown in tables C-1 and C-2 for interurban roads and urban streets, respectively. These tables must be considered as illustrative, not as guideposts. The standards for each country should be designed in the light of its own conditions -- its cost of capital and labor, its rate of economic growth, and its topographic characteristics. Whatever standards are set in a country should generally be maintained to permit efficient road construction, maintenance, and administration, as well as efficiency in the traffic use of the country's highways. Individual road characteristics may have to be modified to meet particular local conditions, but such deviations from national standards should be exceptional and the reasons for them should be made explicit. The PPA analyst should receive the information needed to refer to national standards and to appraise any deviation needed because of local conditions. Where no national standards have been developed, he may refer for guidance to a sample set of standards (such as those of table C-1 or table C-2) in order to judge whether the proposed standards are internally consistent and in accord with the expected traffic demand.

TABLE C-1. GEOMETRIC DESIGN FOR ROADS IN LESS DEVELOPED AREAS

Design Controls and Elements	Class A Road* Four-Lane Road			Class B Road** Two-Lane Road			Class C Road** Two-Lane Road			Class D Road** Two-Lane Road			Class E Road** Two-Lane Road			Class F Road** Single-Lane Road		
	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous
DESIGN CONTROLS:																		
1. Traffic composition 1/																		
T=0%																		
Average daily traffic	6700	6700	6700	4800-6000	4800-6000	4800-6000	3000-4800	3000-4800	3000-4800	1000-3000	1000-3000	1000-3000	70-1000	70-1000	70-1000	Under 70	Under 70	Under 70
Design hourly volume 2/	1000	1000	1000	720-900	720-900	720-900	450-720	450-720	450-720	150-450	150-450	150-450	10-150	10-150	10-150	Under 10	Under 10	Under 10
T=10%																		
Average daily traffic	6000	5100	4000	4400-5500	3700-4600	2800-3500	2700-4400	2300-3700	1800-2800	950-2700	770-2300	600-1800	60-950	53-770	40-600	Under 60	Under 53	Under 40
Design hourly volume 3/	900	770	590	650-820	550-690	420-530	410-650	340-550	270-420	140-410	115-340	90-270	9-140	8-115	6-90	Under 9	Under 8	Under 6
T=20%																		
Average daily traffic	5600	4200	2800	4000-5000	3000-3700	2000-2500	2500-4000	1900-3000	1250-2000	870-2500	630-1900	400-1250	53-870	40-630	27-400	Under 53	Under 40	Under 27
Design hourly volume 3/	840	620	420	600-750	450-560	300-380	380-600	280-450	190-300	130-380	95-280	60-190	8-130	6-95	4-60	Under 8	Under 6	Under 4
T=30%																		
Average daily traffic	5100	3500	2100	3700-4700	2500-3200	1500-2100	2300-3700	1600-2500	970-1500	770-2300	570-1600	330-970	47-770	34-570	20-330	Under 47	Under 34	Under 20
Design hourly volume 3/	770	530	320	550-700	380-480	230-310	340-550	240-380	145-230	115-340	85-240	50-145	7-115	5-85	3-50	Under 7	Under 5	Under 3
2. Design speed, mph	70	60	50	70	60	50	60	50	50	55	45	35	55	45	35	30	25	20
3. Average running speed, mph	49	45	40	49	45	40	45	40	40	43	37	30	43	37	30	27	23	19
CROSS-SECTION ELEMENTS:																		
4. Pavements																		
Minimum width of traffic lanes, 4/ ft																		
With barrier curbs	12	12	12	12	12	12	12	11	11	10	10	10	10	10	10	10	9	8
Without barrier curbs	12	12	12	12	12	12	12	11	11	10	10	10	10	10	10	12	11	10
Minimum distance between barrier curbs, 5/ ft	53	53	53	29	29	29	28	26	26	24	24	24	20	20	20	15	14	13
Desirable lateral clearance to obstructions, ft	6	6	6	6	6	6	6	6	6	4	4	4	2	2	2	2	2	2
Normal cross slope, in./ft	1/8 to 1/4									3/16 to 3/8			1/4 to 1/2					
5. Shoulders 6/																		
Minimum width, shoulders on roads without barrier curbs, ft	10	10	8	10	8	8	10	8	8	8	6	4	6	6	4	4	4	4
Normal cross slope, in./ft	3/8 to 1/2									1/2 to 3/4			3/4 to 1					
Type	Dustless and stable for all-weather use									Stabilized with select material			Compacted soil					
DESIGN ELEMENTS:																		
6. Sight Distance																		
Minimum stopping sight distance, ft	600	475	350	600	475	350	475	350	350	415	310	240	415	310	240	400	300	200
Minimum passing sight distance, ft				2300	2000	1700	2000	1700	1700	1850	1500	1050	1850	1500	1050			
7. Horizontal alignment																		
Horizontal curves																		
Maximum curvature																		
Desirable maximum	1°30'	2°00'	3°00'	1°30'	2°00'	3°00'	2°00'	3°00'	4°00'	2°30'	3°30'	6°00'	2°30'	3°30'	6°00'	8°00'	8°00'	12°00'
Absolute maximum 7/																		
Where snow and ice are not factors	4°00'	5°30'	8°00'	4°00'	5°30'	8°00'	5°30'	8°00'	8°00'	7°00'	10°30'	18°00'	7°00'	10°30	18°00'	25°00'	36°00'	58°00'
Where snow and ice are factors	3°00'	4°30'	7°00'	3°00'	4°30'	7°00'	4°30'	7°00'	7°00'	5°45'	9°00'	16°30'	5°45'	9°00'	16°30'	21°00'	31°00'	58°00'
8. Vertical alignment																		
Grade																		
Desirable maximum																		
Percent	3	3	4	3	3	4	4	5	6	4	5	6	5	6	7	6	6	7
Critical length 8/ ft	1035	1035	720	1035	1035	720	720	550	450	720	550	450	550	450	375	450	450	375
Absolute max for permanent installations																		
Percent	5	6	6	5	6	6	6	7	8	7	8	9	8	9	10	10	10	10
Critical length 8/ ft	1000	660	450	1000	660	450	875	575	500	850	550	275	900	600	400	450	325	225
Absolute max for temporary installations																		
Percent				6	7	8	6	7	8	8	9	10	10	11	12	12	12	12
Critical length 8/ ft				825	550	325	875	550	500	750	500	250	700	525	375	450	300	200
Minimum percent	0.3									0.5								
Vertical curves 9/																		
K for determining safe length																		
Crest vertical curves	240	150	80	240	150	80	150	80	80	115	65	40	115	65	40	28	24	15
Sag vertical curves	140	100	70	140	100	70	100	70	70	85	60	45	85	60	45	35	29	18
Minimum length, ft	210	180	150	210	180	150	180	150	150	165	135	105	165	135	105	90	75	60

Note:

* The design hourly volume (DHV) shown for class A roads is in vehicles per hour per lane for direction of heavier flow.

** The DHV shown for classes B, C, D, E, and F roads is in total vehicles per hour for all lanes in both directions.

1 The symbol "T." with percentage limitations, represents the proportion of total traffic composed of buses & trucks; the remainder are light delivery trucks and passenger cars.

2 The DHV is equal to approximately 15% of the average daily traffic (ADT).

3 These values show the mixed traffic volume which requires the same operational area as that required by traffic composed of light delivery trucks and passenger cars. These DHV's are based on the indicated percentage of the daily volume and may be overconservative in some instances because the percentages of trucks, track-laying vehicles, etc., during peak hours are generally considerably lower than the average percentage during all hours.

4 The traffic lane widths indicated are for use on roads where the traffic will consist principally of vehicles with maximum over-all widths of 8 ft or less. For determining traffic lane width for excessive-width vehicles.

5 Distance shown is the minimum distance between face of curbs.

6 There should be a color or textural contrast between pavement and shoulder surface sufficient to clearly define the pavement and shoulders in all types of weather.

7 Absolute maximum values shown were calculated on the basis of a maximum rate of superelevation of 0.10. Absolute value for horizontal curves will have to be recalculated if a maximum rate of superelevation other than 0.10 is used.

8 The term "critical length" is used to indicate the maximum length of a designated upgrade upon which a loaded truck can operate without an unreasonable reduction in speed.

9 The minimum lengths of vertical curves are determined by multiplying "K" times the algebraic difference of grades (in percent).

TABLE C-2. GEOMETRIC DESIGN FOR STREETS IN LESS DEVELOPED AREAS

Design Controls and Elements	Class A Street* Four-Lane Street		Class B Street** Two-Lane Street		Class C Street** Two-Lane Street		Class D Street** Two-Lane Street		Class E Street** Two-Lane Street		Class F Street** Two-Lane Street	
	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling
DESIGN VARIABLES:												
1. Traffic composition[1]												
Average daily traffic	10,000	10,000	8,400-10,000	8,400-10,000	6,300-8,400	6,300-8,400	2,100-6,300	2,100-6,300	210-2,100	210-2,100	Under 210	Under 210
Design hourly volume[2]	1,200	1,200	1,000-1,200	1,000-1,200	750-1,000	750-1,000	250-750	250-750	25-250	25-250	Under 25	Under 25
Trucks												
Average daily traffic	9,100	7,700	7,600-9,100	6,400-7,700	5,700-7,600	4,800-6,400	1,900-5,700	1,600-4,800	190-1,900	160-1,600	Under 190	Under 160
Design hourly volume[3]	1,090	920	910-1,090	770-920	680-910	580-770	230-680	190-580	23-230	19-190	Under 23	Under 19
Buses												
Average daily traffic	8,300	6,300	6,900-8,300	5,200-6,300	5,200-6,900	3,900-5,200	1,800-5,200	1,300-3,900	170-1,800	130-1,300	Under 170	Under 130
Design hourly volume[3]	1,000	760	830-1,000	625-760	620-830	470-625	220-620	160-470	21-220	16-160	Under 21	Under 16
Passenger cars												
Average daily traffic	7,700	5,300	6,500-7,700	4,700-5,300	4,800-6,500	3,300-4,700	1,600-4,800	1,100-3,300	160-1,600	110-1,100	Under 160	Under 110
Design hourly volume[3]	920	640	780-920	560-640	580-780	400-560	190-580	130-400	19-190	13-130	Under 19	Under 13
2. Design speed, mph	60	50	50	40	50	40	40	30	40	30	40	30
3. Average running speed, mph	38	36	36	32	36	32	32	25	32	25	32	25
CROSS-SECTION ELEMENTS:												
4. Pavements												
Minimum width of lanes,[4] ft												
With barrier curbs												
Traffic	12	12	12	12	12	12	11	11	10	10	10	10
Without barrier curbs												
Traffic	12	12	12	12	12	12	11	11	10	10	10	10
Minimum distance between barrier curbs,[4][5] ft												
Without parking lanes[6]	53	53	29	28	28	28	25	25	20	20	20	20
Desirable lateral clearance to obstructions, ft	6	6	6	6	6	6	4	4	2	2	2	2
Normal cross slope, in./ft	1/8 to 1/4						3/16 to 3/8				1/4 to 1/2	
5. Shoulders[7]												
Minimum width, shoulders on streets without barrier curbs, ft	10	10	10	8	10	8	8	8	8	8	6	8
Normal cross slope, in./ft	3/8 to 1/2						1/2 to 3/4				3/4 to 1	
Type	Dustless and stable for all-weather use											
DESIGN ELEMENTS												
6. Sight distance												
Minimum stopping sight distance, ft	475	350	350	275	350	275	275	200	275	200	275	200
7. Horizontal alignment												
Horizontal curves												
Absolute maximum for normal crown section	0°15'	0°30'	0°30'	0°45'	0°30'	0°45'	0°45'	1°30'	0°45'	1°30'	0°45'	1°30'
Absolute maximum for superelevated section[8]	4°00'	5°30'	5°30'	9°15'	5°30'	9°15'	9°15'	17°15'	9°15'	17°15'	9°15'	17°15'
8. Vertical alignment												
Grade												
Desirable maximum												
Percent	3	3	3	3	3	3	4	4	5	6	6	7
Critical length,[9] ft	800	600	900	550	900	550	750	475	400	200	700	450
Absolute maximum for permanent installations												
Percent	4	5	4	5	5	6	6	7	7	8	10	10
Critical length,[9] ft	900	600	675	400	600	300	500	200	450	175	400	250
Absolute maximum for temporary installations												
Percent			6	6	6	7	7	8	8	9	12	12
Critical length,[9] ft			500	275	500	275	450	200	200	150	400	200
Minimum percent	0.3								0.5			
Vertical curves[10]												
K for determining safe length												
Crest vertical curves	150	80	80	50	80	50	50	28	50	28	50	28
Sag vertical curves	100	70	70	50	70	50	50	35	50	35	50	35
Minimum length, ft	180	150	150	120	150	120	120	90	120	90	120	90

Note:

* The design hourly volume (DHV) shown for class A streets is given in vehicles per hour per lane for direction of heavier flow.

** The DHV shown for classes B, C, D, E, and F streets is given in total vehicles per hour for all lanes in both directions.

1 The symbol "T", with percentage limitations, represents the proportion of total traffic composed of buses and trucks; the remainder are light delivery trucks and passenger cars.

2 The DHV is equal to approximately 12% of the average daily traffic (ADT).

3 These values show the mixed traffic volume which requires the same operational area as that required by traffic composed of light delivery trucks and passenger cars. These DHV's are based on the indicated percentage of the daily volume and may be overconservative in some instances because the percentages of trucks, track-laying vehicles, etc., during peak hours are generally considerably lower than the average percentage during all hours.

4 The traffic and parking lane widths indicated are for use on streets where the traffic will consist principally of vehicles with maximum over-all widths of 8 ft or less. Traffic lanes of streets without curbs in warehouse areas shall not be less than 12 ft regardless of class. The total width of streets with curbs adjacent to warehouses shall not be less than 30 ft between curbs regardless of class. The values given for width of parking lanes is the distance between the outside edge of the adjacent traffic lane and the face of the curb for Type IV curbs. The width of gutter is combined curb and gutter (Types I and III curbs) may be included in the width of parking lane provided the gutter is as strong structurally as the adjoining pavement, otherwise the width of parking lane shown will be the distance between the outside edge of the adjacent traffic lane and the inside edge of the gutter.

5 Distance shown is the minimum distance between face of curbs.

6 Where class E or F streets are designed with barrier curbs, curb offsets are not required adjacent to traffic lanes.

7 There should be a color or textural contrast between pavement and shoulder surface sufficient to clearly define the pavement and shoulders in all types of weather.

8 Absolute maximum values shown were calculated on the basis of a maximum rate of superelevation of 0.02. Superelevation rate of 0.04 or 0.06 may be used on streets in which case the absolute maximum values for horizontal curves will have to be recalculated.

9 The term "critical length" is used to indicate the maximum length of a designated upgrade upon which a loaded truck can operate without an unreasonable reduction in speed.

10 The minimum lengths of vertical curves are determined by multiplying "K" times the algebraic difference of grades (in percent).

APPENDIX D. AVERAGE COST MODULES: HIGHWAY AND STREET CONSTRUCTION

Several tables reflecting average costs experience are presented in this appendix. The scarcity of data in most LDC's may require reliance on generalized cost data of this type. If some but not all components of costs are available, tables D-3 and D-5 may be used to supplement local cost data. In any case, the tables in this appendix can be useful as a check on locally developed cost estimates and on the completeness of the list of cost components.

Should it become desirable or necessary to assess the costs of a proposed project in greater detail than is possible from the data in table D-1, the grading and drainage, the bases, the surfaces, and the structures would each have to be divided into subelements, and the unit price of each subelement would have to be developed. Table D-2 gives these subelements and the unit prices associated with the cost averages shown in table D-1.

It also may become desirable to estimate the total initial cost of a road project from data based on only a portion of the project. To accomplish this, the percentages for the major items of construction have to be developed. If a fairly firm estimate is available for one major element, the total initial cost of a highway project can therefore be estimated. Table D-3 shows the distribution of costs by major highway construction item.

An important phase in the assessment of highway projects is the estimating of material requirements so that domestic sources may be geared to supply such materials. The usage factors, in terms of units of the various materials per million dollars of construction cost, when multiplied by the number of millions of dollars in the project, will generally result in reasonably accurate estimates of material requirements. These usage factors are shown in table D-4.

Table D-1. Estimated Average Costs Per Mile for Rural Highway Construction on New Location

(in thousands of dollars).

Type of construction[a]	Type of terrain		
	Flat	Rolling	Mountainous
Secondary - 24 ft.			
Grading and drainage.....	32	42	101
Base and surfacing..	15	15	16
Structures.....	42	45	58
Total.....	89	102	175
Primary			
24-ft. medium type			
Grading and drainage.....	48	65	154
Base and surfacing.	36	37	39
Structures.....	47	49	63
Total.....	131	151	256
24-ft. high type			
Grading and drainage.....	55	71	166
Base and surfacing.	102	104	110
Structures.....	54	56	70
Total.....	211	231	346
Four 12-ft. lanes - divided			
Grading and drainage.....	251	296	531
Base and surfacing..	217	220	225
Structures.....	311	317	348
Total.....	779	833	1,104

a/ Definitions of surfacing:

Secondary - 0.6" bituminous surface treatment on 8" gravel base, and shoulders.

Primary, medium type - 3" bituminous plant mix medium surface on 5" macadam base on 4" gravel subbase with 6" gravel shoulders each 6 feet wide.

High type - Average of 3" bituminous concrete surface on 18" of base and subbase and 9" portland cement concrete surface on 6" gravel base, each including necessary shoulder construction.

Source: Derived from Department of Transportation, Federal Highway Administration, Bureau of Public Roads Source Data.

Table D-2. Average Bid Prices for Major Items on Highway Construction Projects, 1968

Major items[a]	Unit	Weighted average contract unit price
Grading and drainage		
Roadway excavation:		
Borrow.....	Cubic yard	$ 0.77
Common.....	Cubic yard	.57
Unclassified.....	Cubic yard	.74
Solid rock.....	Cubic yard	2.17
Culvert pipe:		
Clay - 6" diameter.....	Linear foot	2.68
Reinforced concrete - 24" diameter.....	Linear foot	9.01
Corrugated steel - 24" diameter.....	Linear foot	8.35
Bases and surfaces		
Bases:		
Gravel and clay gravel...	Ton	1.80
Macadam or stone.....	Ton	2.63
Portland cement concrete.	Square yard[b]	4.48[c]
Bituminous plant mix.....	Ton	5.84
Sufaces:		
Bituminous concrete.....	Ton	6.77
Portland cement.....	Square yard[d]	4.76[c]
Pavement reinforcement...	Pound	.117
Liquid bitumens:		
Prime, tack and seal.....	Gallon	.183
Structures[e]		
Structural concrete[f].....	Cubic yard	71.81
Structural reinforcement...	Pound	.131
Structural steel.....	Pound	.249
Steel H-piling.....	Pound	.136
Prestressed concrete I-beams:		
36-inch depth.....	Linear foot	17.76
45-inch depth.....	Linear foot	20.95

a/ Total cost of major items is 65.3 percent of total contract cost.
b/ Weighted average thickness is 7.0 inches.
c/ Excludes costs of reinforcement and joints.
d/ Weighted average thickness is 8.8 inches.
e/ Includes bridges, box culverts, retaining walls, tunnels, etc.
f/ Includes superstructure concrete, substructure concrete, and concrete for foundations and footings.

Source: Derived from BPR Source Data.

Table D-3. Distribution of Costs for Highway Construction Items

Major items	All primary		
	Rural	Urban	Total
	------- percent ---------		
Grading and drainage			
Roadway excavation:			
Borrow.....	8.6	6.5	7.7
Common.....	9.5	6.3	8.2
Unclassified.....	18.9	11.8	16.0
Solid rock.....	0.9	1.0	1.0
Culvert pipe:			
Clay - 6".....	0.1	0.1	0.1
Reinforced concrete - 24"..	0.4	0.3	0.4
Corrugated steel - 24".....	0.1	0.1	0.1
Subtotal.....	38.5	26.1	33.5
Bases and surfaces			
Bases:			
Gravel and clay gravel.....	5.8	3.8	5.0
Macadam or stone.....	4.1	1.5	3.1
Portland cement concrete[a].	0.2	0.9	0.5
Bituminous plant mix.....	4.6	2.6	3.8
Surfaces:			
Bituminous concrete.....	7.8	4.4	6.4
Portland cement concrete[a].	12.2	10.3	11.4
Pavement reinforcement.....	2.3	1.6	2.0
Liquid bitumens:			
Prime, tack, and seal.....	0.7	0.3	0.5
Subtotal.....	37.7	25.4	32.7
Structures[b]			
Structural concrete[c].....	12.4	23.3	16.8
Structural reinforcement.....	4.1	8.0	5.7
Structural steel.....	6.0	14.6	9.5
Steel H-piling.....	0.9	2.2	1.4
Prestressed concrete I-beams:			
36-inch depth.....	0.1	0.1	0.1
45-inch depth.....	0.3	0.3	0.3
Subtotal.....	23.8	48.5	33.8
Total.....	100.0	100.0	100.0
Ratio of total amount bid for major items to total amount bid for all items.....	68.0	60.6	64.8

continued--

Table D-3. Distribution of Costs for Highway Construction Items continued --

a/ Excludes costs of reinforcement and joints.
b/ Includes costs of bridges, box culverts, retaining walls, tunnels, etc.
c/ Includes costs of superstructure concrete, substructure concrete and concrete for foundations and footings; excludes cost of reinforcing steel.

Source: Derived from BPR Source Data.

Table D-4. Usage Factors for Ascertaining Amounts of Materials and Labor for Roads

Items	Unit	Number of units per million dollars of construction cost[a]
Cement (excludes cement in concrete pipe).....	Barrels	15,200
Bituminous material.....	Tons	933
Aggregates:[b]		
Purchased (by contractors).	Tons	49,000
Produced (by contractors)..	Tons	35,000
Steel:		
Structural (shape, plates, H and sheet piling).....	Tons	183
Reinforcing (pavement and structural reinforcement).	Tons	232
Culvert pipe (corrugated metal and structural plate, pipe arches and arches).....	Tons	20
Miscellaneous joint devices, tubular piling, etc.....	Tons	24
Concrete pipe (plain and reinforced).....	Tons	369
Clay pipe and tile.....	Tons	11
Lumber (all lumber products except timber piling).....	Board feet	54,000
Timber piling.....	Linear feet	1,000
Petroleum products[c].....	Gallons	131,000
Explosives (excludes weights of caps and fuses).....	Pounds	43,000
Fencing (all types).....	Linear feet	10,400
Guardrail (all types).....	Linear feet	4,200
Bridge railing (all types)...	Linear feet	840
Corrugated aluminum culvert..	Pounds	220
Cast iron pipe.....	Tons	5
Signs (complete in place)....	Dollars	9,200
Lighting (complete in place).	Dollars	7,700
Labor.....	Man-hours	72,000

a/ Right-of-way, preliminary engineering and construction engineering costs excluded.

b/ Includes sand, gravel, clay gravel, slag, crushed stone, etc. used for all highway construction including bases, subbases, concrete surfaces, bituminous surfaces, structural concrete and drainage work.

c/ Fuel and lubricants for equipment and trucks. Grease converted to gallons on basis of 8 pounds per gallon.

Source: Derived from McGraw-Hill Source Data.

Table D-5. Distribution of Costs for Materials, Labor and Equipment for Highway Projects

Items	All primary		
	Rural	Urban	Total
	---------- percent -------		
Cement[a/]	4.3	2.7	3.6
Aggregates purchased[b/]	9.1	8.3	8.7
Bitumens[c/]	2.0	0.4	1.4
Lumber	0.5	0.9	0.6
Timber piling	0.1	0.1	0.1
Corrugated steel culvert pipe	0.9	0.3	0.7
Reinforcing steel[d/]	3.5	4.7	4.0
Structural steel	2.6	6.1	4.0
Ready-mix concrete	3.7	6.8	4.9
Premixed bituminous paving materials	4.0	2.7	3.4
Aggregates produced[e/]	0.6	0.2	0.4
Concrete culvert pipe	0.8	1.5	1.1
Clay pipe	0.1	0.1	0.1
Miscellaneous steel	0.8	1.6	1.2
Fencing	0.8	0.2	0.6
Guardrail	1.4	1.1	1.3
Bridge rail	0.5	0.4	0.5
Petroleum products[f/]	4.9	2.6	4.0
Explosives	2.2	0.2	1.4
Materials not reported	2.1	9.0	4.9
Total materials	44.9	49.9	46.9
Labor	25.8	25.1	25.5
Equipment, overhead, and profit	29.3	25.0	27.6
Total	100.0	100.0	100.0

a/ Does not include cost of cement in ready-mix concrete or in concrete culvert pipe.
b/ Does not include cost of aggregates in ready-mix concrete, premixed bituminous paving materials, or concrete culvert pipe.
c/ Does not include cost of bitumens in premixed bituminous paving materials.

continued--

Table D-5. Distribution of Costs for Materials, Labor and Equipment for Highway Projects continued--

d/ Does not include cost of reinforcing steel in concrete culvert pipe.
e/ Includes estimated royalty payments only. Other costs are included in items of "petroleum products," "labor," and "equipment, overhead, and profit."
f/ Costs of fuel and lubricants for equipment and trucks.

Source: Derived from McGraw-Hill Source Data.

Table D-6. Cost Factors for Geographic Areas

Location	Factor	Location	Factor
Algeria.....	1.30	Jamaica.....	1.20
Ascension Is.....	2.50	Korea.....	0.90
Azores:		Kunsan.....	0.90
Lajes.....	1.10	Osan.....	0.90
Bahama Is.....	1.50	Seoul.....	0.90
Bermuda.....	1.60	Laos.....	0.80
Bikini.....	2.40	Liberia (W. Africa)	0.80
Bolivia.....	1.70	Libya:	
Brazil.....	1.50	Tripoli.....	1.10
British Guiana.....	1.20	Line Is:	
British Honduras.....	1.20	Palmyra.....	2.00
British West Indies:		Majuro Is.....	2.40
Antigua.....	1.40	Morocco.....	1.00
Barbados.....	1.20	Nicaragua.....	1.00
Trinidad.....	1.20	Pakistan:	
Burma.....	1.40	West.....	1.20
Caroline Is:		Palmyra Is.....	2.00
Truk.....	2.00	Panama.....	1.30
Ceylon.....	1.10	Paraguay.....	1.60
Chile.....	1.50	Peru.....	1.50
Christmas Is.....	2.20	Philippine Is.....	1.10
Colombia.....	1.30	Ryuku Is:	
Costa Rica.....	1.00	Okinawa.....	1.00
Ecuador.....	1.50	Saipan.....	2.00
El Salvador.....	1.00	Samoa.....	2.20
Eniwetok.....	2.40	Saudi Arabia:	
Ethiopia.....	0.90	Dhahran.....	1.50
French Guiana.....	1.20	Somaliland.....	1.20
Athenai.....	1.10	Taiwan.....	0.70
Iraklion.....	1.10	Thailand:	
Greenland:		Bangkok, Sattahip.	1.50
Ice Cap.....	4.00	Other areas.....	1.80
Narsarssuak.....	3.50	Tinian (Marianas Is)	2.00
Sonderstrom.....	3.10	Trinidad (BWI).....	1.20
Thule.....	3.50	Uruguay.....	1.60
Guatemala.....	1.00	Venezuela.....	1.30
Iceland.....	3.00	Vietnam:	
India:		Saigon areas.....	2.20
Bombay.....	0.90	Other areas.....	2.50
Iran:		Volcanic Is:	
Tehran.....	0.90	Iwo Jima.....	2.20
Iraq.....	1.30	Wake Is.....	2.20

Source: Extracted from DOD Source Data.

APPENDIX E. RELATIVE COST OF OPERATING AUTOMOBILES ON VARIOUS TYPES OF ROADS

Types of Roads

Vehicle operating costs vary with respect to the types of roads on which they operate. For the purpose of the preliminary assessment of proposed projects, roads have been classified into three types: high, intermediate, and low.

High-type roads are heavier, more durable and more costly. They are commonly referred to as pavements. Portland cement concrete (PCC), sheet asphalt, asphaltic concrete (A/C) brick and the various block pavements are high-type surfaces. The high-type road is composed of a foundation with a long life and renewable wearing surface that permits overlayment when the original surface needs replacing. High-type roads are designed to support large traffic volumes of automobiles and heavy trucks. The initial cost of high-type roads range from two to ten times the cost of intermediate roads. However, over the years, with heavy traffic, the decreased annual maintenance costs and the lower vehicle operating costs may more than offset the initial expenditure.

Intermediate-type roads are all-weather roads with flexible surfaces and with a life expectancy of 5 to 15 years. Typical intermediate-type roads consist of heavy section gravel and broken stone surfaces (surface-treated or untreated) and bituminous surfaces, road mix or penetration macadam. The untreated surfaces are suitable for traffic of 50 to 200 vehicles per day. Treated and bituminous surfaces are capable of carrying mixed car and truck traffic to a maximum of approximately 2,000 vehicles per day.

Low-type roads are composed of natural soil, gravel-coated earth and stabilized soil. Traffic on these types of roads is light, and such roads are generally used to carry vehicles to an intermediate- or high-type road.

Cost of Operating Vehicles

For the preliminary assessment of highway projects it is desirable to know the average cost of operating motor vehicles. To develop an average cost, it is necessary to postulate the types of vehicles that will operate over a highway. Accordingly a composite car is postulated. For LDC's it is assumed that smaller and more economic cars would be used. Therefore, the composite car would weigh 2,500 pounds; it would travel 20 miles on 1 gallon of gas and would use 1 quart of oil per 1,000 miles, with a complete oil change every 2,000 miles; and it would travel about 7,000 miles per year. The cost of operating such a car per mile is shown in table E-1.

It is recognized that prices for the various items comprising the cost of operating a motor vehicle will vary from country to country. It is, therefore, necessary for figures to be generated that can be used to judge the general relative costs of operating motor vehicles independent of licensing, storage, interest and insurance payments. The cost variables, therefore, consist of gasoline, oil, tires (and tubes), maintenance and depreciation. A standard table showing cost estimating relationships for the variables and the constants for various types of road surfaces is developed in subsequent paragraphs.

Cost of Operating Vehicles Over Various Types of Roads

Tractive Resistance

To determine the relative cost of operating vehicles over the three different types of roads described above, it is necessary to determine the average tractive resistances, in pounds per ton, for a vehicle speed of 35 miles per hour:

Surface type	Tractive resistance (lb. per ton)
Low.....	160
Intermediate....	110
High.....	70

Gasoline Consumption

If the gasoline consumed in traveling a given distance on a high-type surface were 1 gallon, the corresponding amount consumed in traveling the same distance on intermediate- and low-type roads would be 1.2 and 1.47 gallons, respectively. This gives an indication of the relative difference in cost when only one cost parameter is considered. The cost of operating a vehicle on various types of surfaces for all cost parameters is shown in table E-2.

Relative Costs

As previously stated, gasoline, tires, maintenance and depreciation vary with respect to the type of road. The following tabulation shows these relationships. The lowest figure has been normalized to unity for the purpose of comparison.

Item	High	Intermediate	Low
Gasoline.....	1	1.2	1.47
Tires (and tubes).	1	2.2	2.89
Maintenance.....	1	1.2	1.48
Depreciation.....	1	1.1	1.24

Table E-1. Cost of Operating Composite Automobile

Item	Cost		Percent of total cost
	Approximate annual ($)	Per mile (¢)	
Gasoline ($.65 per gallon).....	227.00	3.24	16.8
Oil ($.60 per quart)....	14.20	.22	1.1
Tires (and tubes).....	83.00	1.18	6.1
Maintenance.....	236.00	3.37	17.4
Depreciation.....	315.00	4.50	23.3
License.....	25.00	.36	1.9
Garage or parking space ($17/mo).....	204.00	2.91	15.1
Interest.....	150.00	2.14	11.1
Insurance.....	96.60	1.38	7.2
Total.....	1,340.80	19.30	100.0

Table E-2. Relative Cost of Operating Automobiles on Various Types of Roads

Item	Approximate cost on three types of surfaces		
	High	Intermediate	Low
	---------- cents per mile -----		
Gasoline (65 cents per gallon).....	2.78	3.34	4.10
Oil.....	.22	.22	.22
Tires (and tubes)....	.80	1.76	2.31
Maintenance.....	3.95	4.75	5.83
Depreciation.....	3.48	3.84	4.33
License.....	.36	.36	.36
Garage.....	2.91	2.91	2.91
Interest.....	2.14	2.14	2.14
Insurance.....	1.38	1.38	1.38
Total.....	18.02	20.70	23.58

APPENDIX F. MAJOR COMPONENTS OF CONSTRUCTION COSTS: RAILWAYS

Major components of railway construction costs are presented in this appendix. The unit cost estimates are based on experience in the United States at prices prevailing in 1968. Thus the unit costs are not likely to be directly applicable in most LDC's. To the extent that the unit costs reflect labor inputs, the figures given are probably higher than those which will be encountered in most LDC's, although productivity per man-day -- as well as daily wage rates -- must be considered in making the adjustment to local costs. On the other hand, imported materials, equipment, and the cost of foreign engineers and supervisory personnel are likely to be higher in the LDC's than the estimates cited in table F-1.

Clearing and Grubbing. Due to variations in the type and density of foliation, the price for clearing and grubbing may range between $315 and $1,260 per acre.

Earthwork. When the grading is light, fills are frequently made from borrow pits (excavations near roads), and the material in cuts is wasted. The price per cubic yard then applies to the sum of the yardage of cut and fill plus shrinkage. This price is usually $2.00 to $3.50 per cubic yard for earth, about $6.00 to $8.00 for loose rock, and $9.00 to $18.50 for solid rock. When earthwork is heavy, care is taken to make the fills from the material in the cuts. Excess fill is disposed of as directed, and the contractor is paid according to the amount excavated.1/ Much depends on length of haul and on local conditions. Projects in the proximity of cities and on lines currently in use will usually be more costly. As an example of the range of costs, the cost per mile of grading for all the railroads in a 191,733-square-mile diversified area with a population of 15 million varied significantly, from $35,000 to $93,000 per mile.

Tunnels. The total cost of this item is affected by many variable factors. Unit costs, however, should not vary

1/ A higher amount may be charged for excavation work if the contractor is also required to construct embankments from the excavated materials.

Table F-1. Cost of Railroads, Estimates of Basic Items of Work for Single-Track Railroads

(1968 U.S. prices)

No.	Description of item	Cost	
		Per foot	Per mile
1	Rail, 100 lb. per yd. @ $140 per ton.....	$4.65	$24,640
2	Spikes, plates, bolts and splice bars.....	1.40	7,390
3	Ties, 6"x8"x8' - 6', 22" on center @ $5.15 each...	2.80	14,790
4	Ballast, 0.5C.Y. (crushed stone @ $2.50/ton).....	1.60	8,450
5	Labor 1.5 hours @ $3.85 per hour.....	5.75	29,960
	Cost for basic items.....	16.20	85,536

VARIABLE ITEMS

No.	Description of item	Cost per mile		
		Flat	Rolling	Mountainous
6	Clearing and grubbing, grading and drainage (average prices).....	$55,000	$71,000	$166,000
	Cost of basic items....	86,000	86,000	86,000
	Total cost of 1 mile of track.....	141,000	157,000	252,000
7	Land; right-of-way, yards and terminals[a].	60,000	60,000	60,000
	Total cost of 1 mile of track including land[a] (item 7).....	201,000	217,000	312,000

a/ Varies according to location and land use. These figures are based on a right-of-way 100 feet wide. This gives 12.1 acres per mile @ $5,000 per acre. This item, as well as others, must be adjusted for local conditions.

significantly. The average of a large number of cases is shown in tabel F-2, condensed from Drinker's Tunneling, and updated to reflect 1968 costs. All costs are for U.S. standards using conventional mining techniques.

Table F-2. Average Cost of Tunnel Construction

Material	Cost per cubic yard				Average total cost per linear foot	
	Excavation		Masonry			
	Single track	Double track	Single track	Double track	Single track	Double track
Hard rock..	$60	$55	$120	$ 83	$700	$144
Loose rock.	31	35	90	104	810	122
Soft ground	36	46	150	105	1,380	1,880

Rails. Tons (2,000 pounds) per mile of track equal 1.76 times the weight of rail per yard in pounds. An allowance of an additional 2 percent for cutting and waste should be made. The freight from mill to delivery point is frequently a considerable gross item. The present mill price for standard 100-pound-per-yard rails is $140 per ton. Light rails are $5 to $44 per ton more than the 100-pound rails. Prices of rail fastenings are about $1.40 per foot.

Crossties. Creosoted ties range in cost from $5.15 to $8.00 per tie.

Frogs, switches and crossings. Switches in place will cost from $2,000 to $4,800 per switch. The cost of a crossing of two railroads will depend on the angle of intersection, and will cost from $1,500.

Ballast. The cost of ballast may run from $8,400 to $15,000 per mile for the best of broken stone. An ordinary

average is $10,000 per mile of track. Quantities and unit costs are given under the heading Track laying.

Track laying. This item includes track laying, surfacing, and hauling track materials from the point of delivery to the places where used. The contract price for track laying alone is frequently $3,500 per mile at present U.S. prices for labor. However, there are many records of track laying by means of special track-laying cars for as little as $600 per mile. Ballasting is sometimes deferred until the road is in operation. The surfacing may then be a separate contract at about $5,050 per mile. Allowing an average figure of $2,210 per mile for the train service, the total cost to the company for these items will average about $7,150 per mile.

Fencing. The cost of fencing will average about $1,750 per mile of fence, or about $3,500 per mile of road when both sides are completely fenced. Often only a small fraction of the total length is fenced.

Buildings and miscellaneous structures. Station buildings and fixtures average $6,650 per mile. Unit allowance for a small frame passenger station is $15.50 per square foot; for platforms, $2.10 per square foot. The unit cost of six section and tool houses averaged $3.90 per square foot of area. The cost of water stations of ordinary capacity will vary from 39 to 51 cents per gallon of capacity. Sign boards cost $70 to $90 each, and whistle posts, mile posts and rail rests cost about $25 each. A Y configuration can take the place of a turntable providing land is available. Using a radius of 300 feet with 100 feet of track for the engine at the tail of the Y, about 1,050 feet of track plus three switches will be required. The tail of the Y will require land for 400 feet from the main track.

Turntables. This item may cost anywhere from $26,300 to $55,000. The turntable itself is made either of cast iron or structural steel, or sometimes of a combination of structural steel trusses with a cast-iron center.

Coaling stations. Coaling stations for steam railroads may vary from a mere platform or bunker from which the coal is shoveled into the tender (although at a considerable cost

per ton) to the very elaborate and costly coal pockets in which coal is deposited by coal conveyors or dumped from cars drawn up an incline, and from which the coal slides through chutes to the tender. The cost must be computed for individual cases. Ash pits likewise vary from a mere pit between the rails to an elaborate adjunct of a coaling station by which the ashes are immediately transported on a conveyor to an ash car.

Terminal grounds. Although the area of terminal grounds may be not more than 3 or 4 percent of the total property area, its gross cost, or its cost per mile of road, may be more than the cost of all the remaining right-of-way. In an 80,000-square-mile area served by a railroad, the valuation of terminal grounds was 71 percent of the total valuation of all the line right-of-way, gravel pits, station grounds and terminal grounds.

Miscellaneous. Shops, roundhouses, and shop tools and machinery will average about 3 percent of the total cost of a road. Snow fences, bridge ticklers, track scales, mail cranes and bumping posts must be allowed for on all large roads, but their relative cost is insignificant. For signals the cost is so variable, depending on the degree of elaborateness of the system, that average unit prices per mile of road would only be misleading.

Telegraph lines. A conservative estimate is $4,400 per mile of road for a single-wire line, or significantly less if poles are very cheap.

Freight on construction materials. This item applies chiefly to transportation of track material such as crossties, rails, etc., and may amount to 1 percent of the cost of the road. Frequently this item is ignored, the freight being added to the cost of each item.

Contingencies. Contingencies are usually estimated at 5 to 10 percent of the total of the preceding items.

Engineering, superintendence and legal services. The cost of these services is frequently 5 percent of all the construction work. The legal work will cost about 1 percent.

Organizational expenses. A minimum of 1 to 1.5 percent of the cost of all construction work is allowed for organizational expenses.