PN AAN 759
ISN-32125

INTERCITY FREIGHT TRANSPORTATION IN DEVELOPING COUNTRIES

SEPTEMBER 1975

James Sloss

Forrest N. Krutter

Luis Claudio Garcia de Souza

TRANSPORTATION SYSTEMS DIVISION

Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

FINAL REPORT

PREPARED FOR THE AGENCY FOR INTERNATIONAL DEVELOPMENT

WASHINGTON, D.C.

ACKNOWLEDGEMENT

This study was sponsored by the M.I.T. Technology Adaptation Program which is funded through a grant from the Agency for International Development, United States Department of State. The views and opinions expressed in this report are, however, those of the authors and do not necessarily reflect those of the sponsors.

We wish to express our appreciation of the cooperation of many government officials of Argentina, Brazil, the Republic of Colombia, and Mexico who not only provided background information on the physical and demographic features c their transportation networks, but who also supplied statistics which were of great use in developing recommendations for the application of advanced planning technologies to their problems in the rail distribution of commodities.

PREFACE

This report is one of a series of publications which describe various studies undertaken under the sponsorship of the Technology Adaptation Program at the Massachusetts Institute of Technology.

In 1971, the United States Department of State, through the Agency for International Development, awarded the Massachusetts Institute of Technology a grant, the purpose of which was to provide support for the development at M.I.T., in concjunction with institutions in selected developing countries, of capabilities useful in the adaptation of technologies and problem-solving techniques to the needs of those countries. At M.I.T., the Technology Adaptation Program provides the means by which the long-term objective for which the A.I.D. grant was made, can be achieved.

This report describes research conducted by the Transportation Systems Division at M.I.T.'s Department of Civil Engineering to devise and test methodologies for identifying and evaluating the effectiveness of railroad networks in developing countries. Innovative techniques, created for assessing the performance of the United States railroad system, have been employed to measure the comparative efficiency and productivity of rail operations in four Latin American countries -- Argentina, Brazil, Colombia, and Mexico. Findings evolving from this research have dealt with specific problems applicable to the four systems in particular and with policy decisions affecting transport investment and organization in developing countries generally.

In the process of making this TAP-supported study, some insight has been gained into how appropriate technologies can be identified and adapted to the needs of developing countries per se, and it is expected that the recommendations developed will serve as a guide to other developing countries for the solution of similar problems which may be encountered there.

Fred Moavenzadeh
Program Director

TABLE OF CONTENTS

I.	INTRODUCTION AND SUMMARY	1
II.	INTEGRATION OF RAILWAY SYSTEMS WITHIN THE OVERALL ECONOMY OF EACH SAMPLE COUNTRY	10
III.	THE ROLES OF RAILROADS IN THE ECONOMIES OF THE FOUR SAMPLE COUNTRIES	53
IV.	ESTIMATION OF DEMAND, USE OF SCREENING MODELS AND OTHER QUANTITATIVE METHODS	77
V.	CONCLUSIONS	87
	APPENDIX A	98
	APPENDIX B	102
	REFERENCES	103

LIST OF FIGURES

FIGURE 1	ANALYSIS FRAMEWORK	11
FIGURE 2	BASIC SUPPLY-DEMAND RELATIONSHIPS	14
FIGURE 3	PERCENTAGE DISTRIBUTION OF DOMESTIC TRAFFIC	29
FIGURE 4	ARGENTINA: INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC	56
FIGURE 5	BRAZIL: INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC	57
FIGURE 6	COLOMBIA: INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC	59
FIGURE 7	MEXICO: INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC	60
FIGURE 8	MAJOR COMMODITIES CARRIED BY BRAZILIAN FEDERAL RAILWAYS	62
FIGURE 9	MAJOR COMMODITIES CARRIED BY COLOMBIAN RAILWAYS	63
FIGURE 10	MAJOR COMMODITIES CARRIED BY MEXICAN RAILWAYS	64
FIGURE 11	ARGENTINE RAILWAYS	71
FIGURE 12	BRAZILIAN FEDERAL RAILWAYS	72
FIGURE 13	COLOMBIAN RAILWAYS	73
FIGURE 14	MEXICAN RAILWAYS	74

LIST OF TABLES

TABLE 1	ARGENTINA: FOREIGN TRADE DISTRIBUTION	18
TABLE 2	ARGENTINA: DISTRIBUTION OF FREIGHT TRAFFIC BY MODE	19
TABLE 3	BRAZIL: PRINCIPAL EXPORTS IN 1970	27
TABLE 4	BRAZIL: PRINCIPAL IMPORTS IN 1970	27
TABLE 5	BRAZIL: FOREIGN TRADE DISTRIBUTION	28
TABLE 6	BRAZIL: INDEXES OF ORE PRODUCTION AND RAIL VOLUME	32
TABLE 7	COLOMBIA: FOREIGN TRADE DISTRIBUTION	38
TABLE 8	SHARES OF ECONOMIC SECTORS IN THE MEXICAN GROSS DOMESTIC PRODUCT	46
TABLE 9	MEXICO: FOREIGN TRADE DISTRIBUTION	47
TABLE 10	MEXICO: INDEXES OF ORE PRODUCTION AND RAIL VOLUME	51
TABLE 11	TREND ANALYSIS	70
TABLE 12	PERFORMANCE MEASURES: 1973	75
TABLE 13	PREDICTED GROWTH OF RAIL TRAFFIC	79
TABLE 14	PARAMETERS FOR ESTIMATING FUTURE LOCOMOTIVE REQUIREMENTS	84
TABLE 15	LOCOMOTIVE REQUIREMENTS ASSUMING CONSTANT PERFORMANCE MEASURES	84
TABLE 16	PARAMETERS FOR ESTIMATING FUTURE FREIGHT CAR REQUIREMENTS	85
TABLE 17	FREIGHT CAR REQUIREMENTS ASSUMING CONSTANT PERFORMANCE MEASURES	86
TABLE 18	SUMMARY OF THE TEST PROGRAM	91
TABLE A	IMPACT OF TRAIN SPEED AND POWER UTILIZATION ON MOTIVE POWER REQUIREMENTS	100

I. INTRODUCTION AND SUMMARY

A. Preface

One of the major factors in economic development is the provision of reasonably economical intercity freight transportation. High transport costs or poor service limit the size of markets in which a producing area can effectively compete and prevent realization by producers of the economies of scale that can be attained with larger markets. The freight network also influences the relative growth and economic well-being of regions of the country and of particular cities and towns. In terms of resource allocation, freight transportation is of critical importance because large amounts of scarce capital, as well as natural resources and labor are necessary to construct, operate, and maintain transport networks.

Initially, and as the transportation system grows, there are numerous trade-offs between operating and maintenance costs, between current and future investments, and between capital, labor, energy, and land inputs. Over the past century the countries of Latin America have built transportation networks of varying composition and degrees of effectiveness. This research project has sought to devise and test methodologies for developing and evaluating the effectiveness of railroad networks through a process of analysis whereby redundant, inefficient utilization of facilities and other problems would be identified. The research team has concentrated on integrating existing methodologies with newly developed techniques (particularly in the rail area) to develop an overall framework for postulating network design alternatives.

A principal objective of this research has been to test the applicability of certain transportation modelling techniques to developing countries in Latin America. These techniques evolved from a study of United States railroad freight operations and economics, now in its fourth year, which has resulted in the publication of seventeen volumes of reports by the Transportation Systems Division, Department of Civil Engineering, at M.I.T. It has been found that certain countries in Latin America provide a fertile area in which to conduct research utilizing the framework for the analysis of network design alternatives employed in the U.S. railroad study.

The first task of our research was to review all existing transport networks in Latin America. The work began with a comparative analysis of transport networks in Latin American countries at various stages of economic growth with special emphasis on historical development, capital and operating costs, modal performance and impact on the economy. These reviews can be found further on in this chapter.

The original plan was to concentrate our studies on one particular country and the preliminary decision was based on the fact that Mexico's railway network showed the closest resemblance to that of the United States. We felt that an analysis of the Mexican railways could serve as an intermediate stage in providing for a transfer of technology from a highly developed system to a relatively underdeveloped one due to Mexico's position on the economic scale of development and its fairly well developed rail network.

However, it was brought to our attention by persons familiar with the political and transportation environments that it would be difficult to secure adequate data from Mexican sources. Furthermore,

we were advised that the chances that any recommendations for improvements in the railway network would be implemented were remote. The constraints of time and funds involved with this project did not warrant the administrative time and expense of attempting to establish a working relationship with Mexican officials which would require several trips of long duration to Mexico City by project participants.

For these reasons, it was decided to limit the project approach to a general overview of networks and rail issues in four major Latin American countries instead of concentrating our efforts on a single country. The countries selected for this project were Mexico, Brazil, Argentina, and Colombia. Due to lack of data covering other Brazilian lines we investigated only the Brazil Federal Railways and all references to the Brazilian Railroads apply to the Federal Railroads. Brief summaries of the rail networks of Bolivia, Chile, Peru, and Uruguay have also been presented to give a wider view of the Latin American transportation picture.

The original goals of this project have been met by this program. It has enabled the research staff to gain an understanding of railway network characteristics and freight transportation problems in the four countries analyzed as well as initiating personal contacts with Latin American government and transport officials and with members of international agencies such as the Agency for International Development, the International Bank for Reconstruction and Development and the Organization of American States. We have also been able to construct a statistical base that will make future work in the area of Latin American freight transport far easier.

B. Overview of Rail Networks of Interest

A brief description of the state of the railroad network studies is included below. Argentina, Brazil, Colombia, and Mexico were chosen because, in order to apply past research in American Railways, we needed to use the most developed Latin American countries that also had sizable rail networks. This adaptation of previous research to the more developed countries of Latin America should serve, in the future, as a stepping-stone to work on the transport problems of lesser developed nations of the world.

It is important to emphasize the fact that each railroad in the sample is owned and operated by a national or regional government agency. This circumstance is of special significance in respect to their operating ratios and general financial performance which, in many instances, reflect government policies beyond those related directly to the earning power of the railways.

The railroad network of many Latin American countries suffers from a diversity of track gauges. The result of different gauges is two and sometimes even three separate rail networks with no possibility of through train runs. Topography is also a major problem in many Latin American countries with the Andes Mountains and other physical barriers making construction of all types of transportation infrastructures enormously expensive.

1. Mexico

Mexico is one of the most developed countries in Latin America. During the nineteen sixties, its Gross National Product grew at a

four percent annual rate. There has been a strong emphasis in Mexico on motor transport with buses accounting for seventy percent of all public passenger traffic, and motor trucks accounting for sixty percent of the total ton-km freight transport. The Mexican government has completed major road construction projects over the last decade with an increase in paved roads of forty percent from 1960 to 1967; motor vehicle registrations have risen dramatically during this interval.

The railway system consists of the National Railway which operates 75 percent of the total route-kms. and five smaller railways, the most important being the Pacific Railroad. The condition of the principal routes of the National Railway's right-of-way is reported by a competent authority to be better than that of any U.S. line. The Mexican government plans to spend nine hundred million dollars in railroad improvements in the next three years. A major problem has been the large recurring operating deficits reported by the railways, which must be financed by the government

2. Brazil

The Brazilian government is currently undertaking a five-year program for Rail Development (1975-1979) with the objective of increasing rail participation in the country's transport sector For the past decade, the country has been experiencing a fast rate of economic growth and demographic expansion. The railroads, however, have not been able to keep up with this growth. In effect, between 1954 and 1973 their share of freight transportation has been steadily decreasing from 29 percent to 16.2 percent.

The rehabilitation of Brazilian railroads, therefore, represents an essential component in the development of the country's economy and in a more efficient allocation of resources and the conservation of scarce petroleum. To achieve this, the program proposes increasing rolling stock, the capacity of freight depots and marshalling yards, developing modern methods of packing, storing, and handling the movement of freight and creating special routes for export traffic.

To implement this program, Brazil is going to invest more than $U.S. 4 billion which makes it clearly one of the most important capital programs to be undertaken in the country. To finance this, 40.9 percent will come from the federal budget and the remaining 59.1 percent from credit operations, including a $175 million loan from the World Bank.

3. Argentina

Argentina is also engaged in modernizing segments of their 40,000 kms. rail network. The main railways, in addition to their widespread domestic network, also connect Argentina with Bolivia, Brazil, Paraguay and Uruguay, and are paralleled by branches of the Pan American Highway. As part of their rail rehabilitation program, the railway administration plans to renew nine-hundred kilometers of track with eight-hundred more kilometers scheduled to be upgraded in the next few years. This work is intended to permit speeds of from 120 to 160 kilometers per hour on certain rail lines.

4. Colombia

The Colombian rail network has been suffering from declines in passenger kilometers and ton-kilometers for a decade despite a railway

modernization program carried out between 1966 and 1972. Part of Colombia's transport problem is that the transport network is separated into different sub-systems centered around five cities which are linked together primarily by highways and air service, due to the mountainous terrain of the country.

Notwithstanding the difficult locational and operational difficulties confronting the Colombian railways due to the country's topography, strenuous efforts are being carried forward to improve the system and attract an increased volume of freight and passengers. A loan from the World Bank of $U.S. 25 million, negotiated in 1973, is being used for 45 percent of the 1974 and 1975 rehabilitation programs. One of several major projects in the planning stages, estimated to cost $U.S. 24 million, would eliminate the presently existing 104 km. break in the rail network between the towns of Armenia and Ibague, which would permit through-rail service between Colombia's principal port, Buenaventura on the Pacific Coast, and the Capital at Bogota.

C. Sequence of Final Report

Chapter Two is devoted to a survey of the general economies of our four sample Latin American countries with concentration on production, topography, transportation network, and international trade. Strong and weak points of the railroads studied are covered.

Chapter Three delineates the role of the railroads in the national economies of Argentina, Brazil, Colombia, and Mexico. In these countries the railroads have not been growing as fast as other transport modes. As in the United States, trucking and water transportation have made great inroads into markets dominated sixty years ago exclusively by the railways. These governments have invested far more in roads than in railroads, causing the railroads to decline in importance and, in a few countries, serious deterioration of infrastructure and equipment has been observed. Trends in freight traffic hauled by rail and by competing modes are examined, together with associated governmental policies. The nature of the principal commodities carried by the different modes also helps to explain the place of the railroads in the overall supply of transportation services, and in the national economies of the respective countries.

Chapter Four adopts the screening models developed in the October 1974 Progress Report on the Study of Methodologies for Developing and Evaluating Effective Rail Networks [25] prepared for the University Grant Program of the U.S. Department of Transportation by the Department of Civil Engineering at M.I.T. to the sample Latin American Railroads. These models have been employed to identify the various trade-offs available for these railroads to meet projections of demand for rail transport in the coming decade. We also investigate the operational requirements needed to meet these projected future demands.

In Chapter Five, the conclusions of this research project are presented. Summaries of findings applicable to each sample country have been included. Using these conclusions, the common problems

of these four Latin American Railroad systems have been identified, as well as problems facing the railroads of developing countries generally. From these findings, there have emerged a number of recommendations for changes in the railroad systems. However, this research should, by no means, be considered an end, but rather the beginning of more comprehensive research into intercity freight transport in developing countries throughout the world. Therefore, we have presented some thoughts on promising areas for future research, including specifically the development of long term commitment to the design and analysis of freight networks in developing countries.

II. INTEGRATION OF RAILWAY SYSTEMS WITHIN THE OVERALL ECONOMY OF EACH SAMPLE COUNTRY

A. General Observations

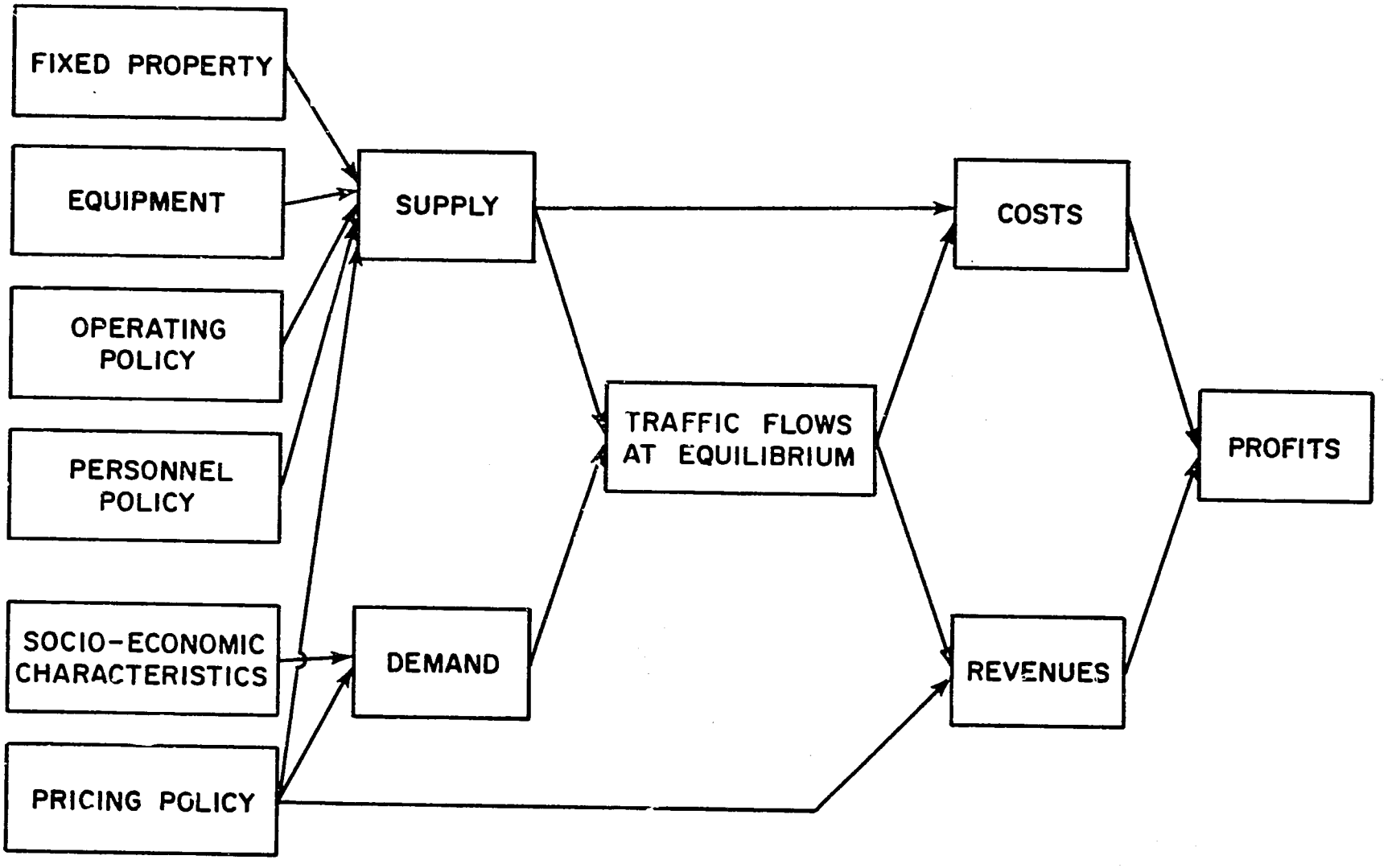
This chapter contains a detailed report on the railroad system for the four sample countries. It is important, however, to understand that the railroad system of any country cannot be dissociated from the overall, multi-modal transportation system of the country. Furthermore, the future of the railroad is closely tied to the complex interactions between supply and demand for freight transportation deriving from the more general characteristics of the economic environment of the country.

The interrelationship between transportation and the socio-economic system is a fundamental concept of transportation systems analysis which stresses that these two forces come to equilibrium to originate the commodity flows which can be measured by statistics of tonnage, modal split and origin and destination pairs.

Figure 1 illustrates the theoretical framework that has been used at M.I.T. for explaining this concept.

The transportation system represents the supply side, which can be specified in terms of network characteristics and a level of service vector including such factors as trip time, trip frequency, trip time reliability, probability of loss and damage and costs to the shipper.

On the demand side, the most important characteristics are those related to population, industry and location of production and consumption centers.



ANALYSIS FRAMEWORK

FIGURE 1

The basic problem lies in the prediction of the equilibrium flows which result from the interaction between supply and demand.

It is within this framework that we shall analyze the various railroad systems. Three basic facts can, therefore, be assumed. Firstly, the demand for rail transportation varies with the economic characteristics of the country, even though railroad installations and services tend to remain fixed in the short run, constituting a potential source of inefficiencies. Secondly, railroads can favorably influence their level of service. Thirdly, by improving level of service, railroads can also bring about long-run economic changes which improve their market position. This fact is particularly important in a developing country context in which major transportation investments may be undertaken for the sole purpose of bringing development to a given region, even though its historical level of production, and consequent traffic potential, might not appear to justify the investment.

The above mentioned improvement of railroad service is what is more strictly defined as "railroad rationalization", i.e. any change in rail networks, operations, policies or equipment that leads to a more efficient use of resources by railroads and shippers. [25]

Rationalization can be achieved through several different but interrelated actions. These could include changes in the infrastructure of the railroads, changes in equipment, changes in operating policies, changes in service and changes in pricing policies, leading to more intensive utilization of the network and enhancing the railroads' competitive position. Diversion of traffic from less efficient modes as well as provision of access to new markets for

commodities whose distribution had been inhibited by excessive transport charges could result from the above listed changes.

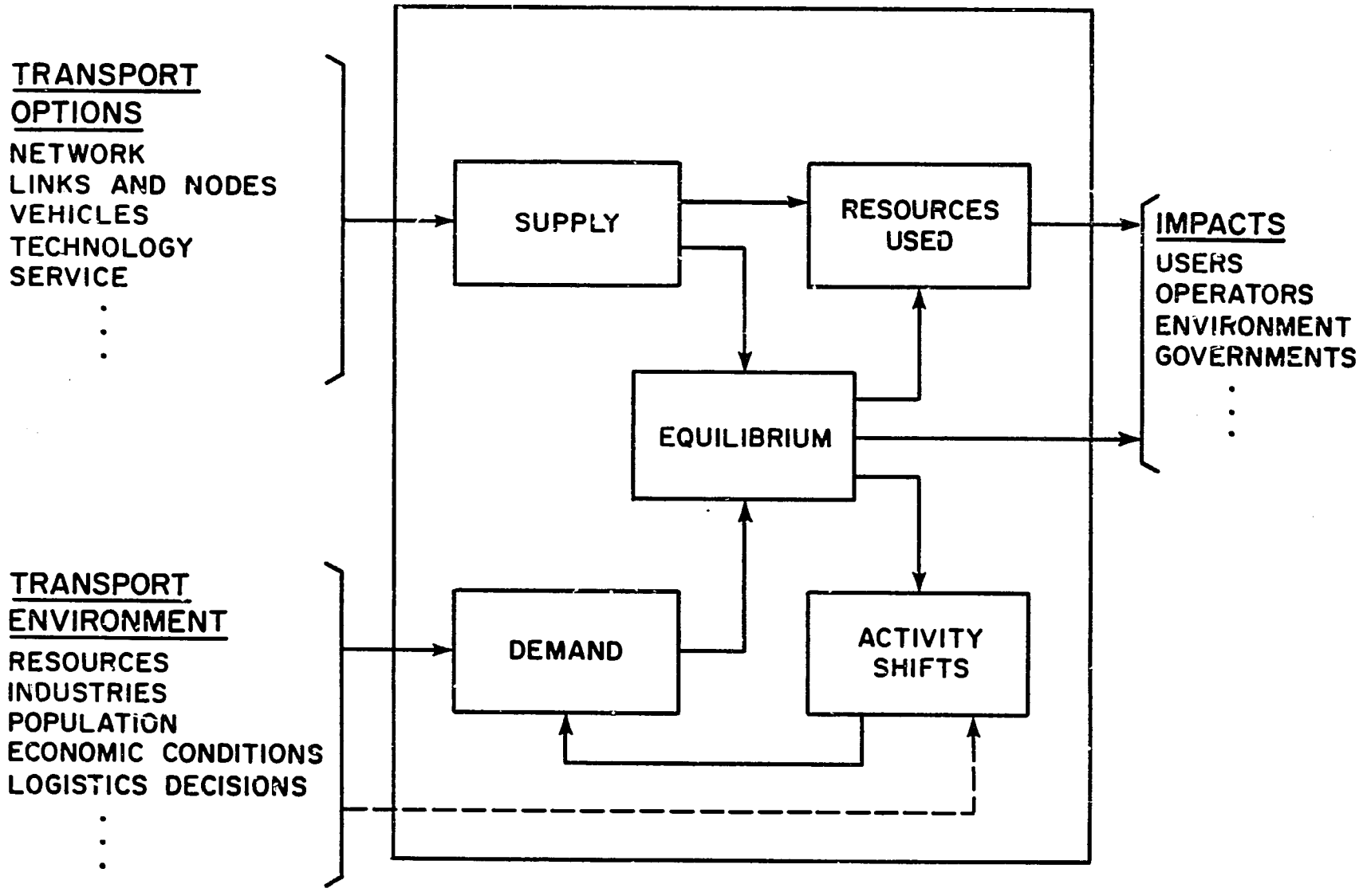
Given that the primary goal of this study is to establish a good background analysis which would enable us to generate such alternatives, evaluate their impacts and identify possible problem areas for more detailed study in each sample country, the present analysis was structured following the methodological framework in Figure 2, which illustrates clearly the interrelationship of the various sectors. The evaluation of the different attributes of the rail system which interact to determine the operating and traffic characteristics of the system will provide insights into the aggregate performance of these systems.

Hence, attention will be focused on the following factors, identifying weak and strong points in each of them:

- Fixed property, including line, signaling, traffic control, communications and yards.
- Equipment.
- Operating policies.
- Personnel policies - preliminary analyses indicate that personnel costs and low productivity per employee constitute a major competitive disadvantage for Latin American railroads.
- Pricing policies.

The above factors define the supply and demand characteristics of the railroad systems and determine the final results in terms of traffic and financial performance.

In order to understand the role of transportation in the context of their respective economic and physical characteristics, a general socioeconomic survey of each sample country is provided in the



BASIC SUPPLY-DEMAND RELATIONSHIPS

FIGURE 2

immediately following sections of this chapter. Relevant background information concerning their commercial and topographical environments is a prerequisite for understanding their transport needs in terms of the requirements of the other sectors of the economy.

B. Argentina

1. Physical Environment

With a continental land mass of about 1,070,000 square miles, Argentina occupies almost the whole of South America below the Tropic of Capricorn and east of the Andes.

The country can be divided into five regions. (1) One of these is the Pampa, a flat and fertile area facing the Atlantic Ocean in the east-central part of the country, which is the cattle and farming center of Argentina and its most populous region. (2) South of the Pampa lies a flatland known as Patagonia, an arid waste of vast distances, incessant winds, very few people and a great many sheep. (3) To the west of the Pampa is the region of the central and northern Andes and their Piedmont approaches which were the first settled parts of the country. (4) In the extreme northeast, rolling prairie and tropical and sub-tropical woodlands occur between the Parana-Uruguay River systems. (5) North of the Pampa is the Argentine sector of a large plateau region known as the Chaco.

Of a population of over 22 million, almost three-quarters live in cities and towns of more than 2,000, and one-third lives in and around Buenos Aires, the most populous metropolitan area in South America.

2. The Economy

Private enterprise accounts for the great bulk of the GNP in Argentina, although the government controls wages, prices and production and participates directly in the fields of natural resource development, utilities, transportation and communications.

The economic policies have been directed at monetary stabilization as the first essential step toward a long-term economic development. Nonetheless, for the last twenty years, the general level of prices has been rising by approximately 25 percent per year. During the same period, the country's real GNP has increased by an average of only 3 percent annually. The country has repeatedly been running budget deficits, half of which can be traced to the state-owned railroads. [1]

a. Agriculture

Argentina is one of the world's leading exporters of cereals and livestock. However, its output is still far below the potential afforded by its rich soils, favorable climate and generally adequate rainfall. Unpredictable and fluctuating pricing and marketing policies have discouraged investment in the agricultural sector. Other restraints have been insufficient rural credit, an unfavorable system of farm tenancy, a deficient system of agricultural education, lack of adequate transportation facilities and a shortage of storage capacity.

In 1966, agriculture was estimated to produce 16 percent of the nation's GNP with 20 percent of the labor force devoted to it. [1]

The major food crops include wheat, corn, barley, oats, rye, grain sorghum, rice and fruits; and the major industrial crops are cottonseed and cottonseed oil, linseed oil and sugar cane. Livestock and livestock products are also very important.

b. Industry and Mining

Although industrial exports in 1968 were relatively insignificant, industry produced about 36 percent of GNP - more than twice that of agriculture. Of this, more than 70 percent originated in the Buenos Aires Province. [1]

The major manufacturing industries produce food, beverages, tobacco, textiles, clothing, leather, chemicals, pharmaceuticals, cement, steel, light machinery and automobiles.

In the mining sector, the country's coal reserves are small and of low quality. Petroleum reserves, although ample, have not been completely developed because of a continuing political debate over foreign participation.

c. Domestic Trade

Wholesale and retail trade contribute approximately 14 percent of GNP and trade, finance and services employ about 43 percent of the total work force. The average annual rate of growth in wholesale and retail trade has been 3.1 percent, a growth which is approximately equal to that of the economy as a whole. [1]

The industrial base is capable of satisfying nearly all demands of the domestic trade. Buenos Aires is the center of trade and as most railroads and highways lead to it, there is little interchange of goods among other regions.

d. Foreign Trade

Argentina, in recent years, has alternatively been running surpluses and deficits in its balance of trade. The major exports include livestock and cereals, whereas imports are raw materials and heavy machinery.

The direction of trade is indicated below:

TABLE 1

ARGENTINA: FOREIGN TRADE DISTRIBUTION

	Exports %	Imports
European Common Market	38	25
Latin American Free Trade Association	15	20
European Free Trade Association	12	13
United States	8	23
Others	27	19
	100	100

Source: [1]

3. Transportation

The transportation system is the most extensive in Latin America, but it suffers from a general lack of coordination, and for several decades has been in a badly deteriorated condition. This deterioration has been most notable in the railroads, and as a result, other means of transportation have had ever-increasing shares in the internal system. The table below clearly shows this for freight transport: [1]

TABLE 2

ARGENTINA: DISTRIBUTION OF FREIGHT TRAFFIC BY MODE

	1950 %	1965
Rail	58.0	20.2
Road	21.0	30.2
Water	20.0	37.2
Pipelines	0.3	11.4
Others	0.7	1.0
TOTAL	100.0	100.0

With almost 40,000 km. of trackage, the Argentine rail system is the longest network in Latin America, and still is the most important means of hauling agricultural products to the ports of export. Concentrated in the Pampa, with one-third in Buenos Aires Province alone, the railroads do not adequately serve the rest of the country. There are many uneconomical lines and the system is so plagued by featherbedding, inadequate maintenance and incompetent administration, that the annual deficit in 1968 amounted to about 112 billion pesos, which was approximately half of the total national budget deficit. [1]

As to road transport, its increasing importance cannot be credited as much to its improved conditions or convenience as to the inadequacy of the railroad system. Much of the traffic now being hauled by road transport could be carried more economically by rail. The capacity of the highway system is insufficient to compensate for the deficiencies of the railroads. In addition to lack of road construction, paving and maintenance in general, most roads in outlying areas merely parallel railroad lines rather than serving as alternate routes and connecting otherwise isolated areas. [1]

Much of the highway transport industry is under government control. Most of the private freight transport companies are single-vehicle operations. Only a few firms are actually registered as common carriers. The government generally permits rates agreed upon by associations to be binding on their members and the flexibility in negotiating routes, schedules and rates has given trucking an advantage over railroads.

Argentina has about 2,000 miles of inland waterways that have been extremely important for the country. Inland water transportation has been developed primarily to carry goods to and from the Rio de la Plata estuary. Ocean-going vessels proceed up the estuary to the port of Rosario and a thousand miles beyond, through the Parana, Uruguay and Paraguay Rivers. The state-owned Inland Waterways Enterprise is responsible for about 30 percent of all river transport trade.

There are some 81 ports, most of which are fluvial, listed by the General Port Administration. In 1963, ten of these ports loaded or unloaded over 1 million metric tons each and the Rio de la Plata ports account for about 55 percent of the total volume of river transport. [1]

a. Present Railroad Situation

Although possessing a generally good alignment and profile dictated by favorable conditions of terrain, the Argentine physical network is handicapped by the gauge problem, with two major networks of 1.676m and 1.000m gauges, and a minor network of standard 1.435m gauge. Furthermore, the existing traffic control system is not suited for a high density of traffic.

Equipment is in less than satisfactory condition, with a high percentage of old and poorly maintained steam locomotives. Diesel locomotives, which constitute the remaining motive power, are also in poor condition, as denoted by the lowest ratio of serviceable to total locomotives of the four sample countries. The average horsepower per diesel locomotive is relatively low and provides a partial explanation for the low average train loadings and for the small average train length

The freight car fleet has a low average capacity considering that more than 50 percent of the equipment is of standard and wide gauge and should therefore have a larger capacity. The equipment is in the worst condition of the four countries studied.

Personnel costs are one of the major sources of deficit on the Argentine railroads, exceeding total revenues by 40 percent. This means that for every dollar of revenue received, a corresponding $1.40 of labor cost is expended. The productivity of labor is low even if compared only with countries showing a similar capital and labor mix.

The operating characteristics show a very poor performance with a low operating efficiency and poor resource utilization. The traffic density and frequency are the lowest of the four sample countries. The percent of empty mileage would be acceptable by U.S. standards; however, the low ratio of average loading to average capacity shows a poor utilization of freight car capacity by the railroads. The approximate car cycle time is the largest of those studied and can be considered large for the actual average length of haul. Also very low, are average car-km and ton-km per serviceable

car-day.

This whole situation is reflected in the poor financial results of the railroads, which, in 1973, showed an operating ratio of 185.

b. Trends

Analyzing the Argentine railroad performance over the years shows a worsening financial situation with ever-increasing operating ratios. Operating characteristics, in terms of traffic density, car utilization and train loadings, denote a very slow improvement compared to Mexico and Brazil. Also, labor productivity, measured in terms of traffic units per employee, which constitutes one of the railroads' major problems, shows the smallest improvement of the four countries.

Summarizing, it may be concluded that the railroad situation in Argentina shows a very definite trend toward deterioration in every aspect.

C. Brazil

1. The Physical Environment

Occupying nearly half of the South American continent, Brazil's total area, 3.3 million square miles, is greater than that of the forty-eight contiguous states of the United States.

Although mostly inside the Tropical Zone, Brazil enjoys a relatively moderate climate, and even in the Amazon Basin, nights are reasonably cool. Nowhere is the temperature extremely high, although humidity in much of the equatorial portion is often oppressive. Rainfall is generally plentiful, but not excessive, although

the precipitation in the Northeast is almost freakishly irregular and has resulted in many catastrophic droughts.

There are twenty-one mountains with heights in excess of 5,000 feet, but being geologically ancient, none reaches as high as 10,000 feet. Half of the country is a plateau area ranging from 500 to 3,000 feet in height above sea level.

The great Amazon River system spills more water into the ocean than any other river in the world, and many other rivers rise in the highlands near the Atlantic coastline, e.g., Sao Francisco, Parana and Paraguay Rivers. They are increasingly used as sources of hydroelectric power, but because they become unnavigable where they plunge off the upland scarp, they are of limited value for navigation in Brazil as inland waterways.

The rolling characteristics of most of the topography are such that little of the country has gradients too abrupt for agricultural use, but prevailing latosol and laterite soils are low in fertility. Furthermore, many soils have been heavily leached of their mineral content; there are, however, excellent soils in the southern states. Extensive deposits of base and precious minerals are widely distributed, especially iron ore and manganese.

The maritime border, along the Atlantic coastline, is 4,600 miles long and has a large number of excellent natural harbors that were the sites of the first settlements, many of which have grown into great cities.

The coastal lowlands and southern plains and plateau remain the most densely populated parts of the country, with 70 percent of a total population of approximately 106 million people. The Central

West and the Northeast highlands have scanty populations and much of the Amazon Basin remains uninhabited. There is a noted migration to the urban centers, and presently only 50 percent of the people live in rural areas. However, a major shift in the settlement pattern, drawing the population inland, has commenced with the construction of the new capital, Brazilia, and the Trans-Amazon highway.

2. The Economy

Since 1964, the basic economic policy objectives of the Brazilian government have been the stabilization of prices, growth of the Gross National Product, and the restoration of a favorable balance in the foreign trade and payments account. Economic policies directed specifically at the stabilization objective included reduction of the fiscal deficit that had been the primary source of inflationary pressures, wage controls, credit restrictions and liberalization of foreign trade. Relaxation of price and rent controls and an increase in public utility rates were policies directed at stimulating investment and increased production, although conflicting with the short term objective of stabilization of prices. Institutions and mechanisms were developed to generate savings and to channel these savings to the more productive sectors of the economy. Measures and policies directed at the elimination of the balance of payment deficit included liberalization of the exchange system, removal of obstacles to exportation and improvement in the financing of exports.

By 1968, the economy began to show signs of recovery. Gross National Product had been growing at an annual rate of 10 percent and

inflation had been reduced to 25-30 percent. [11] Agricultural production and construction have been the leading sectors in generating a continuing demand for industrial production, a higher level of employment, increased investment and rising foreign trade.

a. Agriculture

Agriculture plays a major role in the Brazilian economy, contributing more than 25 percent of total GNP, constituting about 80 percent of the total value of exports and employing more than 50 percent of the labor force. [11]

The main agriculture products in terms of value of production are beef, coffee, corn and rice. Coffee is the major agricultural export followed by cotton, sugar, cocoa, corn, beef and soybeans. Wheat is the most important agricultural import and comes mainly from the United States and Argentina.

b. Industry and Mining

Industry in Brazil accounts for about 35 percent of GNP and employs about 15 percent of the labor force. Exports of manufactured goods, primarily to other Latin American countries, amount to almost 20 percent of total exports. [11]

The industrial sector is concentrated in the triangular area formed by the cities of Sao Paulo, Rio de Janeiro and Belo Horizonte. Their corresponding states together produced 80 percent of the total manufacturing in the country. Other industrial centers include Recife, with food processing and Salvador, with the Araxa Industrial Sector.

The major manufacturing industries are steel with an annual output of around 10 million tons, chemicals, automobiles (now approaching one million vehicles per year), farm machinery, ship-building, electrical equipment, textiles and cement. The production of railroad equipment has been increasing steadily, with exports of locomotives and freight cars to other countries in Latin America.

In the mining sector, the most important minerals produced and exported are iron ore and manganese. Coal and petroleum are also produced, but the coal is of low quality and the oil production only covers 30 percent of domestic consumption.

The trends in industry presage a continued growth in this sector, demanding therefore, continued improvements in power, communications and transportation.

c. Domestic Trade

Domestic trade represents about 13 percent of GNP and employs about 12 percent of the labor force. [11]

Trade practices range from the highly organized modern types to those of underdeveloped agricultural communities. The principal distribution facilities are located in the two metropolitan centers of Rio de Janeiro and Sao Paulo.

An important factor to note is the imbalance in domestic income between the eight southern states and those in the north and northeast. The south, with less than 17 percent of the area and 60 percent of the population accounts for 80 percent of domestic income, whereas the states of the central-west and northeast, with 83 percent of the total area and 40 percent of the population, account only for 19 percent. [11]

d. Foreign Trade

In recent years, the country's exports and imports have been expanding rapidly in response to the government's incentives, which are likely to continue for some time.

The principal exports in 1970 were: [11]

TABLE 3

BRAZIL: PRINCIPAL EXPORTS IN 1970

	$U.S. Million	% of Total
Coffee	982	35.8
Manufactured Goods	455	16.6
Iron Ore	209	7.6
Cotton	154	5.6
Sugar	127	4.6
Others	818	29.8
TOTAL	2,745	100.0

The principal imports were:

TABLE 4

BRAZIL: PRINCIPAL IMPORTS IN 1970

	$U.S. Million	% of Total
Machinery	1,002	35.1
Raw Materials	488	17.1
Chemicals	446	15.7
Manufactured Goods	133	5.6
Others	785	27.5
TOTAL	2,854	100.0

In 1970, the foreign trade had the following distribution between the different countries and associations [11]:

TABLE 5

BRAZIL: FOREIGN TRADE DISTRIBUTION

	Exports $U.S. Million	%	Imports $U.S. Million	%
United States	685	25	912	32
European Common Markets	767	28	627	22
European Free Trade Association	356	13	342	12
Latin American Free Trade Association	301	11	313	11
Eastern Europe	137	5	57	2
Others	493	18	598	21
TOTAL	2,739	100	2,849	100

3. Transportation

The Brazilian transport system developed without proper coordination. Roads and railroads were built in a fan-like pattern, from the interior to the various ports along the coast, with few lateral connecting links. Only in the last fifteen years has the government undertaken a systematic effort to rationalize its network.

The distribution of domestic traffic in percent of ton-kms between the various modes in 1973 is shown in Figure 3. [3]

The disproportionate share of truck transportation results both from the poor performance of the railroads and from the massive investment in highways. Extensive highways have been built to open up new areas for development. These include the Belem-Brasilia route, joining the north to the new Capital, the Trans-Amazon highway, the Santarem-Cuiaba, (under construction near the uppermost border of the country with the Guyanas and Venezuela) all integrating the Amazonic region and the central-west.

PERCENTAGE DISTRIBUTION OF DOMESTIC TRAFFIC

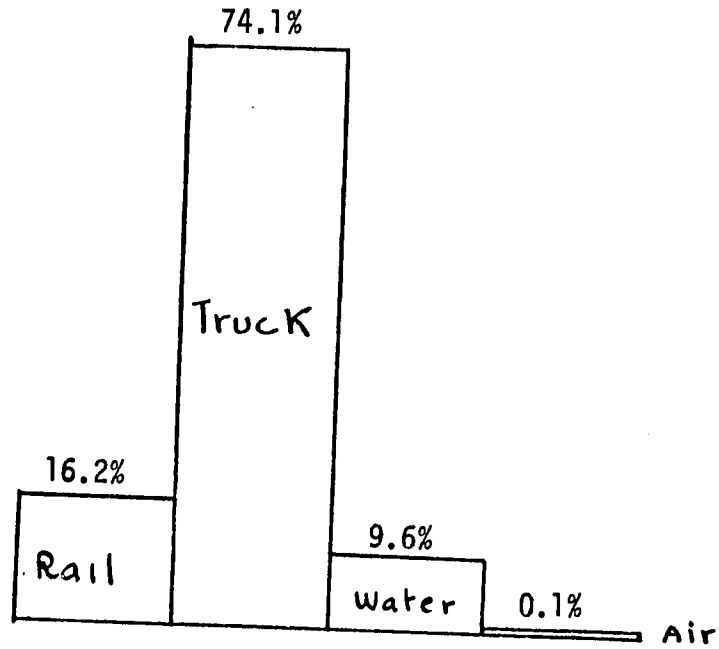


Figure 3

In 1971, the Brazilian highway network included a total of 1.2 million kilometers, including federal, state and local highways. Of these, 54,165 kilometers were paved. During the same year, the number of registered vehicles was 3.5 million for a national average of 36.9 persons per motor vehicle. [3]

The railroads, which are the subject of a more detailed study, infra, have not kept pace with the development of the country and have lost a considerable share of the freight and passenger traffic to road transportation. The government is now endeavoring to rehabilitate the railroads and will begin implementing the National Railway Development Program: 1975-1979, for which substantial funds have been allocated from the budget, as well as from credit operations.

By the end of 1970, ships of the Brazilian merchant fleet aggregated 2.4 million deadweight tons. The government, as owner of

over 80 percent of the ocean-going ships, controls the Lloyd Brasileiro, which is the only Brazilian cargo and passenger company engaged in international maritime shipping. The government also owns the National Tanker fleet, consisting, in 1970, of 41 tankers. [12] Coastwise shipping has been increasing, mostly due to the increase of petroleum transport. In 1970, the coastal fleet comprised 238 ships, 30 percent of which belonged to the government's National Coastal Navigation Company.

In the Amazon River system, transportation services are provided by the federally-controlled Navigation Service of Amazonia. Products moving downstream include timber, nuts, rubber, jute, and rice. On the Parana-Paraguay system, service is furnished by the Navigation Service of the Prata Basin. There is also, as on the Amazon and other rivers with navigable stretches, a large number of small companies with privately-owned rivercraft.

The shipbuilding industry is presently one of the major industries in the country and is playing an increasing role in the provision of ships to the national fleet.

The principal ports are Rio de Janeiro and Santos. They handle 50 percent of the cargo shipped to the 36 major ports in the country, both fluvial and maritime.

Air transportation in Brazil started in 1927 and has had a rapid expansion ever since. However, its share of the total traffic, either of freight or of passengers, is not significant enough to justify its inclusion in the present study. In fact, the figures show that domestic airlines carry only 0.1 percent of total freight and 1.9 percent of intercity passengers in the country.

a. Present Railroad Situation

The Brazilian railroad network, as presently constituted, can be primarily characterized by the existing diversity of gauges. There are basically two different gauges, i.e., 1.60m and 1.00m, because the .76m gauge has little significance in relation to the total network. Although the 1.00m gauge lines represent the majority of route-km of the network, they are not as intensively used as the 1.60m gauge lines which are newer and in better condition. There is a small amount of electrification and, in fact, Brazil has the largest electrified network in Latin America, which, from an energy-saving standpoint can be considered an asset to an oil-importing country. The existing traffic control system, although adequate for the present low density of traffic, would certainly not meet the operational needs in case of a major traffic expansion.

The motive power is in relatively good condition when compared to that of the other three sample countries and is acceptable by U.S. standards. The steam locomotives actually reported are not used for road service and are being gradually retired. However, the average horsepower of diesel and electric locomotives is very low, ruling out any increase in train loading. In fact, the average train length in Brazil is only 20 freight cars with an average of 3.3 locomotives per train. The freight car fleet can be considered in generally acceptable condition, although a quite small average loading capacity per car prevails.

The average productivity per employee is relatively weak; however, one cannot say that personnel is the major cost problem of

Brazilian railroads because it accounts for only 57.5 percent of the total costs, which is the lowest proportion for any of the countries studied. (The percentage of total wage compensation to operating expenses of U.S. railroads in 1974 was 57 percent).

The operational performance measures are generally unimpressive, showing low traffic densities, frequencies and train loadings. Freight car utilization is somewhat better with a reasonable car cycle time between loadings, although the average length of haul for freight is small as compared to U.S. railroads. Average weight per loaded freight car is satisfactory and the ratio of loaded to total car-km is also good.

The railroads, however, are not able to adapt their service to demand changes; this can be illustrated by taking a typical rail-oriented commodity such as iron ore, and comparing time-series indexes of overall mining production and rail transport of iron ore. As shown in the table below, the railroads did not keep pace with the increase in output, which could have been carried by rail. [11]

TABLE 6

BRAZIL: INDEXES OF ORE PRODUCTION AND RAIL VOLUME

Year	Ore Production Index	Rail Transport Index
1970	100	100
1971	110	90
1972	112	80
1973	120	108

The railroad's financial performance can be summarized by noting the 157 operating ratio for the year 1973.

b. Trends

The trends for Brazil are somewhat more encouraging than the analysis of the present situation would indicate. In fact, the figures presented in Table 11 will show the operating ratio declining over the last seven years at a rate unparalleled in Latin America, reflecting the results of various rationalization efforts undertaken by the government. However, the performance indicators related to operating efficiency, train loadings, equipment utilization and labor productivity, although improving, do not show the consistency necessary to attain levels comparable, for instance, with the figures for Mexico.

D. Colombia

1. The Physical Environment

The Repubulic of Colombia is located in the northwest part of the South American continent in the region of the northern Andes. The population is concentrated in the western highlands and in the cities of the Atlantic coastal region. The eastern plains are sparsely settled and, in the present state of technology, afford comparatively little potential for economic exploitation.

Although recently increasing industrialization and expansion of transportation facilities have introduced a new dynamism into the national economy, it still remains heavily dependent on the cultivation and exportation of coffee.

Geography fragments the face of the country with few generalizations applicable to the whole country. Regions differ culturally,

ethnically, and in their economic organization and condition.

The Republic of Colombia comprises some 440,000 square miles with a population of around twenty-two million. The Andes Mountains run northward along the western coast of the continent and dominate the western 2/5 of Colombia, giving it a markedly different character from the eastern 3/5 of the country. [30] The western part of the country presents an extraordinary diversity of elevation, climate and types of land. Elevated basins and plateaus of central-western Colombia enjoy a moderate climate which provides not only pleasant living conditions, but enables the farmers in many places to harvest twice a year. The great majority of the population lives in these temperate regions.

The Andes divide into three main ranges in Colombia; the Western, Central, and Eastern Cordilleras. The eastern-most and longest range diverges from the central range a hundred miles north of Ecuador. The valley between the ranges provides a large drainage area for the Magdalena River. In the Eastern Cordillera at elevations between eight and nine thousand feet a number of fertile savannas are located. Bogota, the Capital and largest city in Colombia, with a population exceeding 2-1/2 million, is located on one of these savannas.

The Central Cordillera is the largest of the mountain ranges. Its crystalline rocks form a 500 mile barrier dotted with volcanoes. There are no plateaus in this range and no passes cross it under 11,000 feet. In a basin twelve miles long lies the city of Medellin, the second largest city in Colombia and a center of population and economic growth.

The Western Cordillera is separated from the Central Cordillera by a deep rift, the Cauca River Valley. The Western Cordillera is the lowest and the least populated of the three ranges and supports little economic activity. A pass about 5,000 feet above sea level provides Cali, the third largest city in Colombia, with an outlet to the Pacific Ocean. The relatively low elevation of the Western Cordillera permits very dense vegetation, which becomes tropical on the western slopes. South of where the Eastern and Central Cordillera branch off, the ranges are divided by an extension of the Cauca River Valley. The mountains force the main travel and communications arteries to run in a north-south direction parallel to the ranges of the Andes.

Although most population centers are closer to the Pacific coast than to the Carribean coast, the Andean ranges have caused surface transport routes generally to traverse relatively long distances to reach Caribbean coastal regions and the seas. East-West communication has been much more limited in extent and a large amount of what exists is of recent origin and has been brought about mainly by technical innovations in the field of transportation such as highway construction and air transport.

The main artery of the central lowlands is the Magdalena River system. Most of the principal population centers of the country have established links of one kind or another with this river system. The Magdalena River is navigable for nine hundred kilometers south of its mouth; the Cauca, San Jorge, and Cesar Rivers are its principal tributaries. The river has been the major factor in the growth of many cities and ports between its mouth at Barranquilla and the

normal head of navigation at La Dorada-Puerto Salgar. [14] The ports of Santa Marta to the east and Cartagena to the southwest compete with Barranquila for a leading commercial role, especially in the export-import trade. Midway between Panama and Ecuador on the Pacific coast is Buenaventura, Colombia's principal port in terms of volume.

Cattle ranches are located on the eastern slopes of the Andes and in the north. The rest of the area to the southeast is covered by dense and largely unexplored rain forest. Tributaries of the Orinoco and Amazon Rivers and air services provide the main lines of transportation to, from and within this region.

2. The Economy

The economy of Colombia is based on agriculture, livestock production, minerals production and miscellaneous industry.

a. Agriculture

Principal agricultural commodities raised include coffee, cotton, maize, sugar cane and bananas. Cattle are also produced for domestic consumption and for export, although the shipping of cattle out of the country has diminished since the formation of the European Common Market. Coffee is by far the most important crop providing 75 to 85 percent of the country's exports in monetary terms.

b. Industry and Mining

Manufacturing represents one of the most important facets of the Colombian economy. Among the leading articles of domestic output are soft drinks, other foodstuffs, textiles, refined petroleum products,

Renault automobiles, cement, clothing and shoes. The three most important centers of economic activity are the cities of Bogota in the Cordillera Oriental, Medellin in the Cordillera Central and Cali in the Western Valley.

Large quantities of petroleum have been discovered in various parts of Colombia, particularly in the department of Santander in the northeast, and in the departments of Huila and those on the Colombia-Ecuador border. Principal refineries are situated at Barrancabermeja on the Magdalena River and at Cartagena on the Caribbean Coast. It is proposed to construct a refinery at Tumaco on the Pacific Ocean to process crude oil from the fields in Southwestern Colombia, which can then be shipped by tankers to Caribbean ports via the Panama Canal and to Buenaventura for delivery to Cali and other cities in the Cauca River Valley. Colombia is presently able to produce sufficient quantities of petroleum products to satisfy its domestic requirements.

Commercial quantities of coal are also found in parts of Colombia. This is high quality coal suitable for metallurgical purposes. Much of it is mined in the vicinity of Sogamoso in the department of Boyaca and shipped to a nearby steel mill whose products are distributed to major consuming areas throughout Colombia. A prospective export market for coal will be dependent on the development of an economical means of delivering this commodity to seaports, a service which is not presently available. A variety of other minerals are found in Colombia of which the most important, from a transportation viewpoint, is cement produced in large quantities in the area around Puerto Boyaca.

c. Foreign Trade

The balance of payments and major commodities exported and imported, respectively, are shown on Table 7:

TABLE 7
COLOMBIA: FOREIGN TRADE DISTRIBUTION
($U.S. 1,000)

	Exports	%	Imports	%
U.S. and Canada	309,168	44.8	262,613	32.7
Central America Common Market	6,619	1.0	159	0.02
Latin America Free Trade Association	101,698	14.7	65,006	8.1
European Free Trade Association	68,776	10.0	69,411	8.6
European Common Market	179,719	26.0	119,930	14.9
Eastern Europe	18,067	2.6	7,603	0.9
Others	5,962	0.9	278,037	34.6
TOTAL	690,009	100.0	802,759	100.0

Major Exports (1970) [23]	
Coffee	63.5%
Oil	9.9%
Manufactured goods	5.7%
Cotton	4.7%
Sugar	1.9%

Major Imports (1970) [23]	
Chemicals	16.3%
Manufactured goods	17.8%
Machinery	46.5%

3. Transportation

Due to the rugged topography of Colombia, the transport network is separated into different sub-systems centered around five key cities with airlines and highways connecting all major Colombian cities. Highway carriers and pipelines share the bulk of freight transport between these centers. The air cargo system links all major centers and the jungle areas of the southeast. The intercoastal system through the Panama Canal consist of one route between Cartagena and Buenaventura with most traffic moving from the Atlantic to the Pacific.

The river system, especially the Rio Magdalena, continues to be very intensively used though it has shown little change since the end of World War II in relative importance. Mostly bulk raw materials are transported between the many inland ports on this system; in 1972 oil products accounted for 79 percent of the tonnage transported on the Magdalena. Rivers are the only means of surface transport in the jungles of the southeast and in the Choco Department, which is along the Pacific Ocean. The upper reaches of the Magdalena River's use as a means of transport has been limited by seasonal fluctuations in the water level. Above Gamarra, available depths in the navigable channels become increasingly worse and can be navigated only with difficulty during the dry seasons. [14] These periods occur twice a year and last about three months each.

The Canal del Dique connects the Magdalena River with the Caribbean seaport of Cartagena. Because of heavy silt deposits, the canal must be dredged continuously in order to preserve its eight-foot depth. The port of Barranquilla, at the mouth of the Magdalena served, until World War II, only as a river port. Since then, constant dredging and the construction of canals and breakwaters have made possible the entry of ocean vessels of up to 10,000 tons. Pipelines represent the principal form of transport for crude oil and petroleum products and the products pipeline system is over 1,300 kms in length. Fuel oil is shipped from refineries by barge, railroad and truck. [14]

Until 1959, the rail system was largely three separate networks. Connectivity has improved since then with the completion in 1960 of the Atlantico railroad line which established a link between the previously isolated western network serving the Buenaventura-Cali-Medellin area and the eastern network serving Bogota-La Dorada-Ibague and connected them with the Carribean port of Santa Marta. In 1973, the rail link between Medellin and Cali was severed by a flooding of the Cauca River and no decision has been reached as to its restoration or abandonment.

The highway system is a joint responsibility of the national and departmental governments. There were in 1972, 6,600 km of paved highways out of a total network of 50,000 route-km. Sections of the country, formerly inaccessible, except by mule paths, have now become linked with population centers by means of motor transport, although thousands of miles of pack trails still exist and serve as the only means of access to remote places nestled among the mountains.

Topography is the major factor in determining the shape of the Colombian transport network. The topography of the country has necessitated the selection of a variety of modes to solve the different transport problems facing each of the key developing areas of Colombia.

a. Present Railroad Situation

Any analysis of the Colombian railroad situation has to take into consideration the scale of its network as compared to those of larger countries. For example, the Argentine network is more than ten times as large as the Colombian network. Also, the levels of economic activity in Colombia are much smaller, originating lesser sized traffic flows. Therefore, comparisons between Colombia's railroad and the other three sample railroad systems must be judged accordingly.

The Colombian network has a single gauge of 0.914m. Although uniform, this narrow gauge poses problems such as restricted capacity, decreased stability, and lower operating speeds. It also has no automatic blocking or signaling systems which might be difficult to justify due to the present light traffic density.

The locomotives are almost all diesel with only a very few steam locomotives still in service. The present locomotives fleet is in an acceptable condition as the ratio of serviceable to total locomotives is reasonable, judged by the standards of maintenance generally found in Latin America. However, the low horsepower of locomotives leads to small train loadings with freight trains averaging only 16 cars for 2.5 locomotives. This problem is

aggravated by the 4 percent grade on the main line where it leaves the Magdalena River Valley at Puerto Salgar and climbs to the 8600 foot altitude of Bogota.

The freight cars seem also in good condition and have a good average capacity comparable to the wider gauge Brazilian equipment. This freight capacity, however, is poorly utilized, showing a ratio of average tons per car load to average capacity of only 0.70 as compared to Brazil's 0.90 and Mexico's 0.80.

Personnel productivity may be considered somewhat low and labor costs approximate 63 percent of total costs.

The Colombian Railroad's operating performance has the characteristics of a low density network. In some cases, however, it shows better results, especially in respect to traffic density and train loading, than the much larger Argentine network. A good average percentage of empty to loaded kilometrage has been achieved but a very long freight car cycle time prevails, averaging 18 days per car. [14]

The operating ratio, 129.6 for 1972, is the lowest of the four countries included in the present study. [21]

b. Trends

A study of several performance indicators for the Colombian Railroad network over time indicates an improvement in operating ratios since 1967. It will be observed in a subsequent chapter that this financial result does not appear to be related to an amelioration in operating performance measures such as traffic density, equipment utilization or labor productivity, which show

only very modest increases for the same period. [13]

E. Mexico

1. The Physical Environment

Linking North America to the Central American isthmus, Mexico has a total area of 760,337 square miles. Two major mountain chains, the Eastern Sierra Madre and the Western Sierra Madre, cross the country from north to south forming between them a number of valleys and plateaus extending from Puebla northward into the southwestern part of the Untied States. With a few exceptions, the principal cities are in these areas of relatively high fertility. Between the mountains and the coast are tropical coastal plains. South and southeast of Mexico City lie the broken plateaus of the Mesa del Sur and Chiopas Highlands. The peninsulas of Yucatan and Baja California complete the territory.

Vegetation is sparse in the extensive desert and semi-arid regions of northern and central Mexico, but extensive forests are found in the interior plateaus. Because of its wide range of altitude, Mexico has a greatly diversified climate, ranging from tropical to cold.

Mexico has a population of 50,700,000 concentrated mostly on the uplands of the central zone and parts of the south. Twenty percent inhabit the State of Mexico and the Federal District, which includes Mexico City.

The rivers have little importance as commercial waterways. However, the lower courses of the Rio Bravo and the Panuco are

navigable by ocean-going vessels as far as the ports of Matamoros and Tampico, and the lower Coatzacoalcos is navigable as far as Minatitlan.

2. The Economy

For Mexico, the last 20 years have been predominantly a period of industrialization. During this period, few developing countries have shown comparable sustained growth. In this process, although Mexico remains basically a private enterprise economy, the government has played a vital role in economic management. However, some problems still exist and others have emerged. Manufacturers are heavily subsidized, population growth continues to accelerate, complicating efforts to raise educational standards, and the rural population constitutes a depressed sector of the economy.

a. Agriculture

Agriculture accounts for about a quarter of the national income, although only 15 percent of Mexico's land is suitable for cultivation and over 40 percent of the usable land requires artificial irrigation. [21] Reduced farm production, due to adverse weather conditions, led to serious reprecussions on the food supply in 1973. The principal crops are maize, wheat, cotton, sugar cane, coffee, fruits and alfalfa. The forests provide a variety of hard and soft woods.

b. Industry and Mining

In 1967, industry (mining, manufacturing, construction and power) accounted for 22.3 percent of the GNP. [21] Manufacturing

plays a major role in the economy and represents 26.5 percent of GNP. However, most of the establishments are small shops, which contribute little to the total value of the product. A major problem of achieving economies of scale is also identifiable in the steel and chemical industries, which operate with excess capacity. Major industrial products are processed food, synthetic fibers, steel, sulfuric acid, glass products, freight cars, assembled automobiles and malt beverages. Eighty percent of all consumer goods are now made in Mexico.

Mexico's wealth in gold and silver has always attracted the attention of foreigners, but has been decreasing steadily in importance. These metals now come as by-products from the exploitation of the complex sulfide ores containing lead and zinc, of which Mexico is a leading producer. There are also significant deposits of copper, oil and natural gas. Mexico, however, is generally deficient in iron, ferro-alloy metals and coal.

Mexico is a moderately large producer of crude petroleum and natural gas with sizable reserves. Exports of these items equate to $U.S. 31 million in 1971, whereas importation of petroleum products amounted to $U.S. 57 million. [29]

The trends indicate that the average annual rate of increase in manufactured products during the past two decades has been around 8 percent. In the accelerating process of development, which has been going on in Mexico since World War II, important structural changes have occurred, the relative position of the extractive industry having changed little between 1950 and 1967, its portion of the gross domestic product (GDP) rising from 4.5 to 4.7 percent.

Within that sector the relative importance of metallic minerals diminished while sulfur and common salt emerged as items of major importance.

From 1950 to 1967, manufacturing increased its share of the work force from 11.8 to 15.7 percent, with a rise in its portion of the GDP from 18.3 to 26.5 percent. In Table 8 may be seen the changing shares of different components of the GDP.

TABLE 8

SHARES OF ECONOMIC SECTORS IN THE MEXICAN GROSS DOMESTIC PRODUCT 1950-67

	Percentage of Gross Domestic Product	
	1950	1967
Agriculture, stock raising, forestries and fisheries	19.6	15.8
Extractive Industry	4.5	4.7
Manufacturing	18.3	26.5
Construction	1.8	3.9
Electric Power	0.5	1.5
Transport and Communications	4.3	4.1
Commerce and Finance	32.4	26.0
Miscellaneous Services	18.6	17.5

c. Foreign Trade

Mexico is presently running a deficit in its balance of trade. However, this deficit reflects an attempt to obtain a more balanced and more highly industrialized economy, since the deficit is produced by an excess of capital goods imports over total exports.

Main agriculture exports include cotton, sugar, coffee, meat and corn. Petroleum, sulphur and salt are Mexico's most important mineral exports. Manufactured exports are still based on primary products such as foodstuffs, chemicals and textiles, but items such as books, electrical equipment, machinery parts and specialty industrial products are becoming increasingly important.

Major imports include machinery, industrial equipment, tractors, telephone and telegraph equipment, earth moving equipment and other capital equipment.

The composition of foreign trade in 1967 is indicated in Table 9:

TABLE 9

MEXICO: FOREIGN TRADE DISTRIBUTION

	Exports %	Imports
United States	62.9	62.9
European Common Market	9.6	15.8
European Free Trade Association	5.9	8.3
Latin American Free Trade Association[1]	4.9	2.2
Rest of Latin America[2]	4.6	0.9
Eastern Europe	0.3	0.3
Japan	7.0	4.3
Others	4.8	5.3
TOTAL	100.0	100.0

[1]excludes Venezuela
[2]excludes Cuba

3. Transportation

Mexico has a reasonably comprehensive domestic transportation system, serving all economically important areas, notwithstanding the generally mountainous terrain and the lack of navigable inland waterways. The approximate distribution of freight between the various modes for the year 1967 is given below in ton-km. [21] The volume of air freight was relatively small and does not appear in the figures.

Road	60%
Rail	30%
Pipelines	10%

The Mexican highway system has undergone recent expansion and by 1973 there were 160,000 km of all-weather roads, of which some 60% were paved. It is reported that there were 2.4 million motor vehicles registered in 1973 including 645,000 trucks. Sales of large trucks having gross vehicular weights exceeding 26,000 pounds increased from 389 in 1960 to 5,051 in 1970 or 1,300 percent.

The Mexican rail system attained a substantial part of its present size early in this century. It is, on the whole, an interconnected, integrated network of standard gauge (1.435m). Built originally by a number of private enterprises, it was subsequently nationalized in stages, but never brought under a unified management. The separate entities of railroads in operation are listed below together with their length in km:

National Railroad of Mexico (NDM)	13,164 Km.
Pacific Railroad (FCP)	2,140 Km.
Chihuahua - Pacific Railroad (CHP)	1,514 Km.
United Southeast Railroad (UDS)	1,366 Km.
Sonora - Baja California Railroad (SBC)	521 Km.
Western Railroad of Mexico (ODM)	38 Km.
TOTAL LENGTH	18,743 Km.

Regarding domestic air transportation, Mexico is well supplied and there are few population centers of any consequence that are not served by licensed common carriers on either a scheduled or non-scheduled basis. Any change in concessionaires, schedules, routes, equipment, and rates requires prior approval of the Ministry of Communications and Transport.

The most important airlines operating domestic services include the government owned Aeromexico S.A., the Compania Mexicana de Aviacion, an affiliate of Pan American Airways, and Servicios Aereos Especiales.

Pipeline transportation has also come to play an important role in the Mexican economy, since mineral hydrocarbons are the predominant source of power, not only for transportation but for industry as well. At the end of 1966, the total length of the pipeline system was around 8,000 miles, of which 3,300 miles were for natural gas, 2,100 miles for petroleum products and 2,400 miles for crude oil.

In addition to the modes described above, Mexico is making a great effort to develop its merchant marine. At the end of 1967, however, there were still only 556,000 tons under Mexican registry, of which 64 percent were ocean-going (mainly tankers).

Port conditions in Mexico are generally unsatisfactory. Although the country is not well served with natural harbors, present difficulties are largely administrative in origin, especially in the area of labor-management relations.

a. Present Railroad Situation

The Mexican railroad network provides the best rail service in Latin America.

It has two gauges -- the standard 1.435m gauge and a narrow 0.914m gauge -- without, however, creating a problem because the main network is of standard width and the 5.5 percent of narrow gauge constitutes only relatively unimportant branch lines. Its physical characteristics were shaped by the generally rugged terrain so that only 26 percent has a grade of less than 0.5 percent. The extensive use of automatic blocking systems on Mexican lines permits higher densities of traffic than would otherwise be possible.

The locomotive stock is almost entirely dieselized with a good average horsepower per unit, which enables the assembling of the longest trains in Latin America despite adverse geographic conditions. The equipment seems to be well maintained except for the few electric locomotives which show a low ratio of serviceability to total locomotives.

The freight cars have the highest average capacity of the four sample countries and are in good condition judged by the best U.S. standards. Personnel figures show the highest productivity measures of any Latin American system; labor costs account for less than 60 percent of total costs.

The Mexican Rail system also proves sensitive to increases in demand. As Table 10 below shows, the increase in production of iron ore, unlike in Brazil, was accompanied by a corresponding increase in transportation of iron ore by rail. [20]

TABLE 10

MEXICO: INDEXES OF ORE PRODUCTION AND RAIL VOLUME

Year	Ore Production Index	Rail Transport Index
1968	100	100
1969	107	107
1970	114	129
1971	121	129
1972	120	132
1973	122	132

The supply characteristics of the Mexican Railways are also the best in Latin America in terms of operating efficiency, such as traffic density, frequency and train loadings. In terms of freight car utilization, the Mexican figures compare with the best U.S. railroads whether related to car cycle time, car-km or ton-km per serviceable car-day.

However, in spite of the good performance demonstrated above, the Mexican railroads have constantly been running a deficit, and in 1973 their operating ratio was up to 176. No accurate information is available in regard to rate policies, but there are indications that the rate structure has not reflected the real cost of transport and this seems to be one of the main causes of the financial distress experienced by the railroads. However, in December of 1974, the government authorized an increase in freight rates of about 30

percent. This increase, the first since 1959, will undoubtedly ameliorate the situation.

b. Trends

The trends for the Mexican railroads show a significant rate of improvement in operating performance and labor productivity. The operating ratio, however, shows an ever-increasing upward trend with rising deficits which the government, as owner of the railroads, may not be willing to sustain for an indefinite period of time.

III. THE ROLE OF RAILROADS IN THE ECONOMIES OF THE FOUR SAMPLE COUNTRIES

A. Trends in the Growth or Decline of Railroad Freight Volume

The railroads were a major factor in the growth of the developed nations during the nineteenth century and have the potential of promoting economic growth in the developing countries of the twentieth century. However, they can only serve this purpose if their inherent advantage is fully exploited.

Developing countries have historically exported bulk agricultural and mineral products in exchange for manufactured products and for capital equipment to be used to facilitate internal industrialization. A more efficient transportation network can bring down transport costs, thus increasing the size of the country's domestic and foreign markets for its raw materials and manufactures. To the purchaser of a good, the transport charge is an integral portion of the cost; thus a decrease in transport costs should increase the quantity demanded. Many of today's developing countries experience increasing returns to scale as their industries are far below the optimal size for efficient operation. Thus, an increase in market size will allow expansion of industry, which, with increasing returns to scale, will allow further per-unit cost reductions.

This can also be the case in the agricultural and mining sectors. A variety of cash crops will be encouraged when transport costs are lowered allowing them to compete in the world market. Mineral resources that are not now exploited because high transport costs make them too expensive may be developed. For commodities that are competitive and for which the demand is elastic over the

relevant range, increases in production due to reductions in transport costs are important to the development of a country. For non-competitive goods and those for which demand is inelastic, reductions in transport costs can increase the profit to the producing country from the sale of such goods.

Returning to the 19th century United States, the Midwest and Great Plains did not become the world's breadbasket until lower transport costs provided by the railroads' expansion reduced prices on the Eastern Seaboard and in Western Europe below the price of home grown wheat. We believe that the railroads today have a potentially comparable role in providing the low cost transport which is needed to promote the economies of developing countries. Bulk agricultural and mineral products, as well as many processed goods, can be transported by rail efficiently and cheaply, provided there is an adequate rail network and a reliable level of service.

In this chapter, the present role of the railroads in Argentina, Brazil, Colombia and Mexico in relation to the national economies of these countries is reviewed. Growth of total product expressed in constant prices has been compared with trends in rail freight to discover how the volume of rail traffic changed relative to the national economy. Cases where the national product has grown much faster than rail traffic support an inference that other modes have been diverting freight from the railroads. Overall, for the four countries studied, we found a correlation coefficient between the growth of total product at constant prices and the growth of rail traffic to be +0.733.

In Argentina, rail freight has not kept up with the growth of the economy. Looking at Figure 4, one can see a rather steady 6.7 percent annual growth rate of the economy. Rail volume was erratic experiencing both increases and decreases between 1965 and 1972. The marked decline in rail freight in 1967 was due to labor problems. The failure of the railroads to match the growth of the national economy is reflected in the increase in truck registrations since 1965 accompanied by a decline in the amount of cargo shipped on the railroads. Figure 4 also demonstrates that the index of truck registrations had climbed by 1971 to 136 from a 1965 base of 100 while net ton-kms of railway freight had declined to an index level of 93.

Brazil's railroads have grown rapidly in the last decade. Their pace in this period has been highly correlated with the growth of the national economy. The emphasis the government of Brazil has recently placed on the development of an efficient rail network has caused the railroads to show some significant improvements. In Figure 5, the high correlation between the growth of the economy and rail freight traffic on the Brazilian railways can be seen. Figure 5 also compares the growth of Brazil's total railway freight, the Federal Railway's share and truck registrations. The rapid growth of ton-kilometers for all railways since 1968 has been due mainly to the increase in iron-ore traffic. The large amount of iron-ore carried in unit trains is portrayed on Figure 8, which shows the principal commodities carried by the railroads in Brazil.

Even though rail freight traffic has been increasing, the railroads' market share of all goods transported decreased from 24 percent

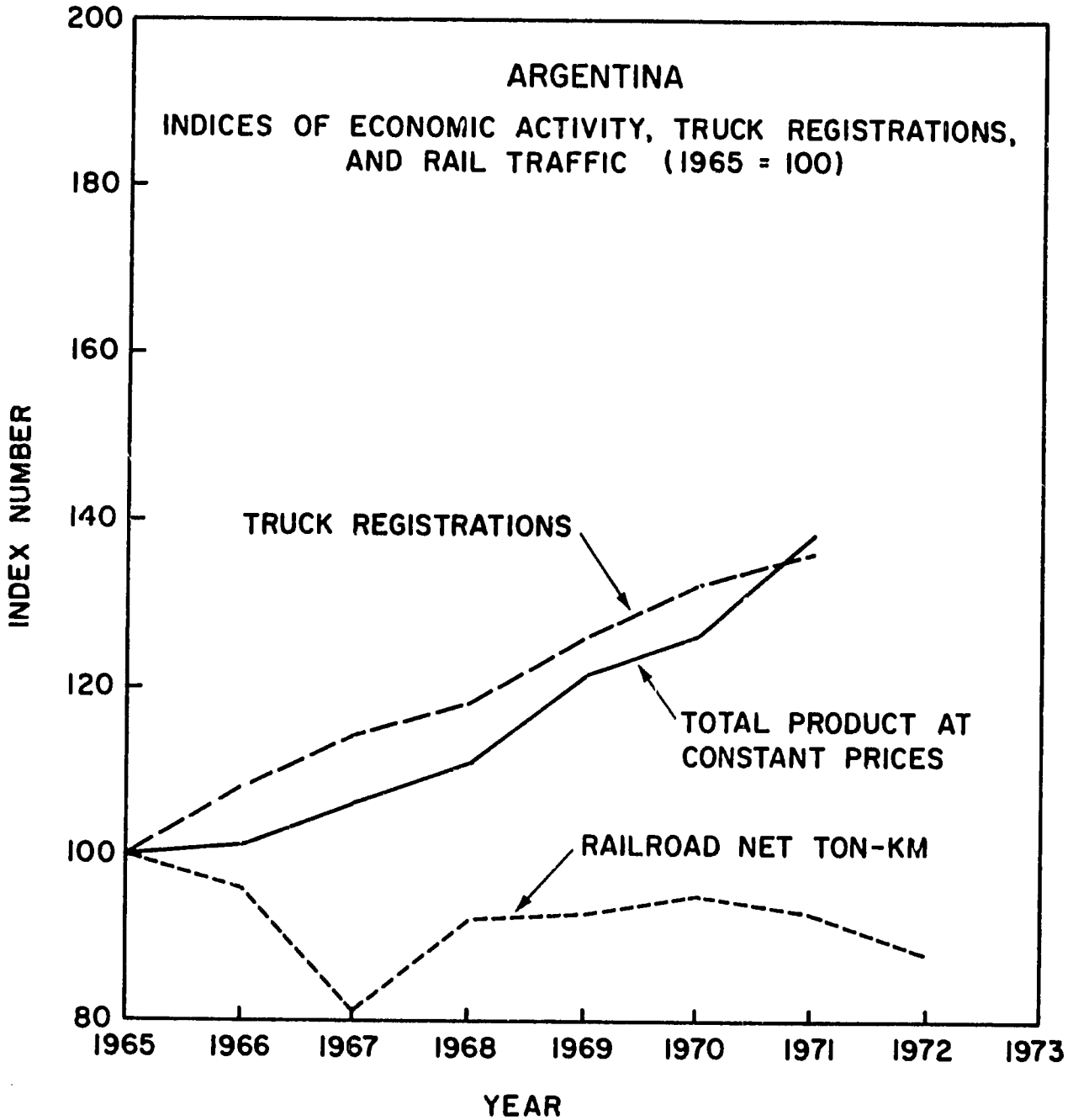

ARGENTINA
INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC (1965 = 100)
INDEX NUMBER
200
180
160
140
120
100
80
TRUCK REGISTRATIONS
TOTAL PRODUCT AT CONSTANT PRICES
RAILROAD NET TON-KM
1965
1966
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 4

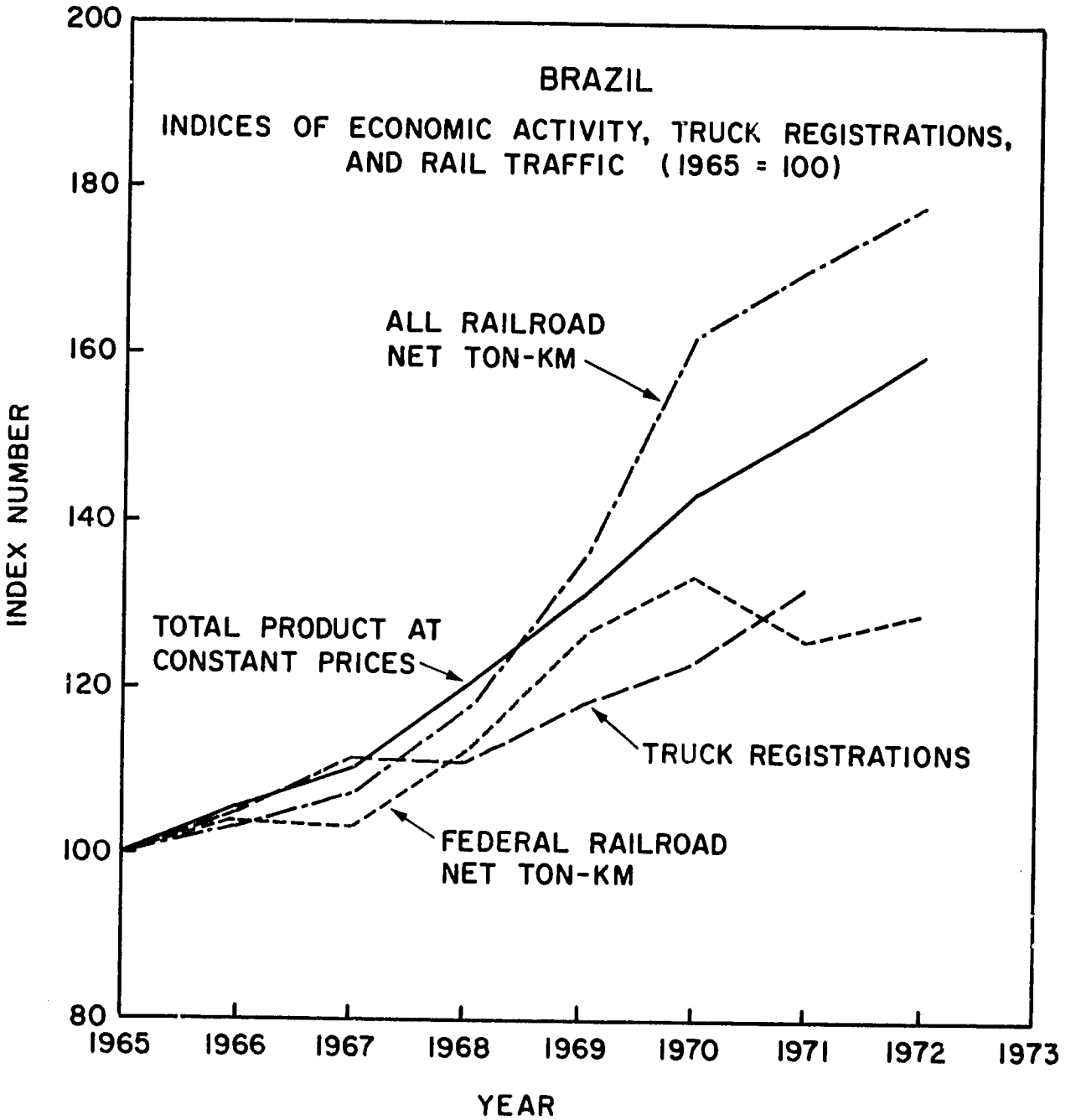

BRAZIL
INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC (1965 = 100)
ALL RAILROAD NET TON-KM
TOTAL PRODUCT AT CONSTANT PRICES
TRUCK REGISTRATIONS
FEDERAL RAILROAD NET TON-KM
INDEX NUMBER
200
180
160
140
120
100
80
1965
1966
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 5

to 16 percent between 1950 and 1973, so it is doubtful that the railroads, during this 23 year span, actually kept pace with the economy. Figure 5 may be biased upward by recent improvements in the railroads' competitive posture.

Since 1968, Colombia's railroads have not grown as fast as the national economy. For one thing, in 1970 and again in 1973 the rail link between Medellin and Cali was severed by flooding and has not been reconstructed, necessitating diversion of certain freight in the Cauca River Valley to other modes. Figure 6 indicates rates of growth of the national economy and of rail ton-kilometers since 1963. Rail freight traffic levels have remained stationary since 1969, suggesting that other modes are increasing their share of the transport market at the expense of the railroads. Figures on Colombia's truck registrations have shown inconsistencies since 1968, making a continuous time series of registrations statistically unreliable.

Mexico has shown rapid growth in total product at constant prices, rail freight traffic, and truck registrations. Each of these measures has grown at similar rates and even though Mexico has invested heavily in its highway network, it appears that the railroads have retained their share of the market over the past decade. This circumstance is illustrated in Figure 7.

The railroads of the Latin American countries in our sample largely serve to carry bulk commodities. For example, the chief commodity carried by the railroads of Brazil is iron-ore. Eighty percent of this traffic is carried by the Victoria-Minas Railroad which runs unit trains from the mines to Victoria for re-shipment

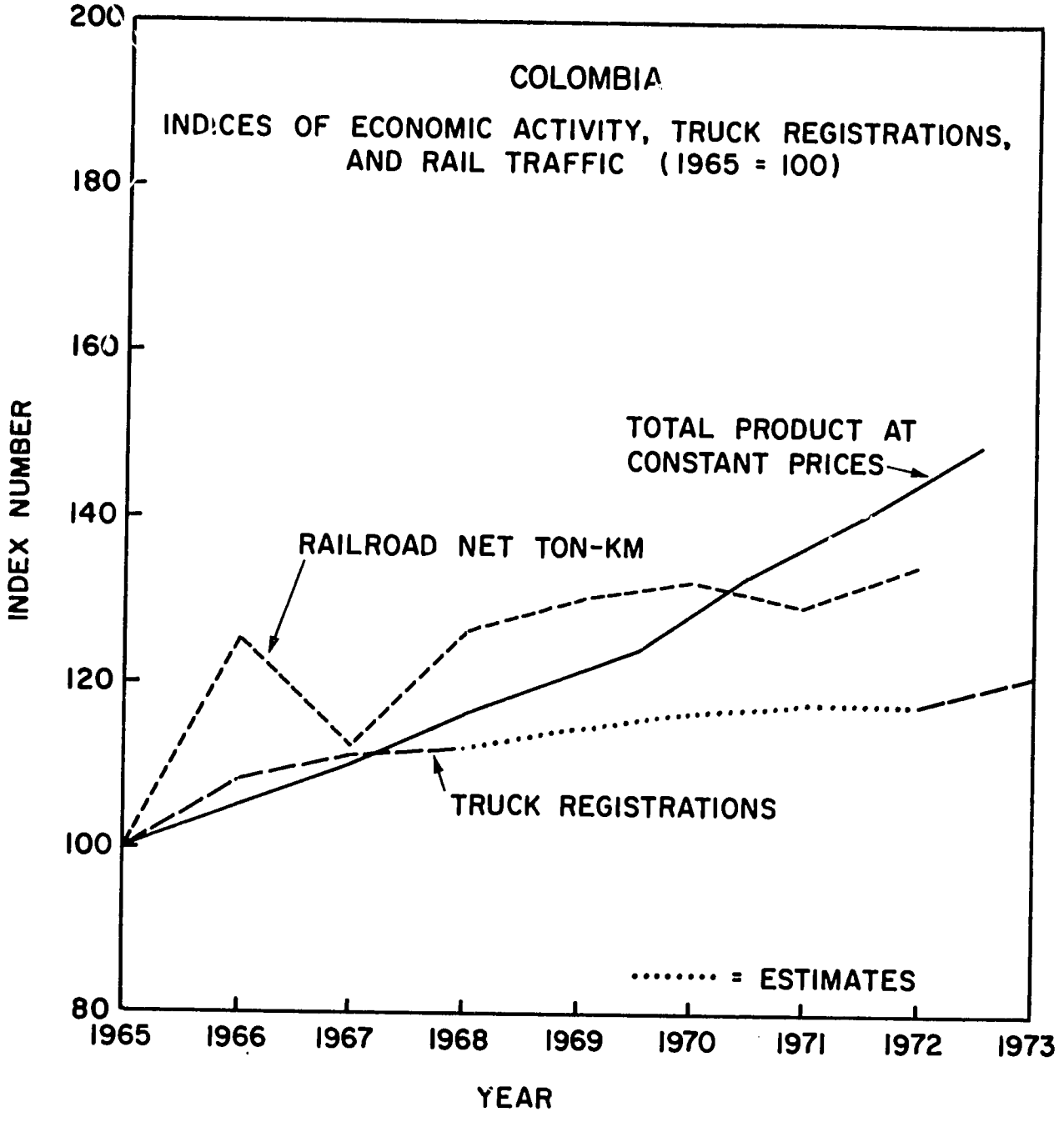

COLOMBIA
INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC (1965 = 100)
INDEX NUMBER
200
180
160
140
120
100
80
TOTAL PRODUCT AT CONSTANT PRICES
RAILROAD NET TON-KM
TRUCK REGISTRATIONS
····· = ESTIMATES
1965
1966
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 6

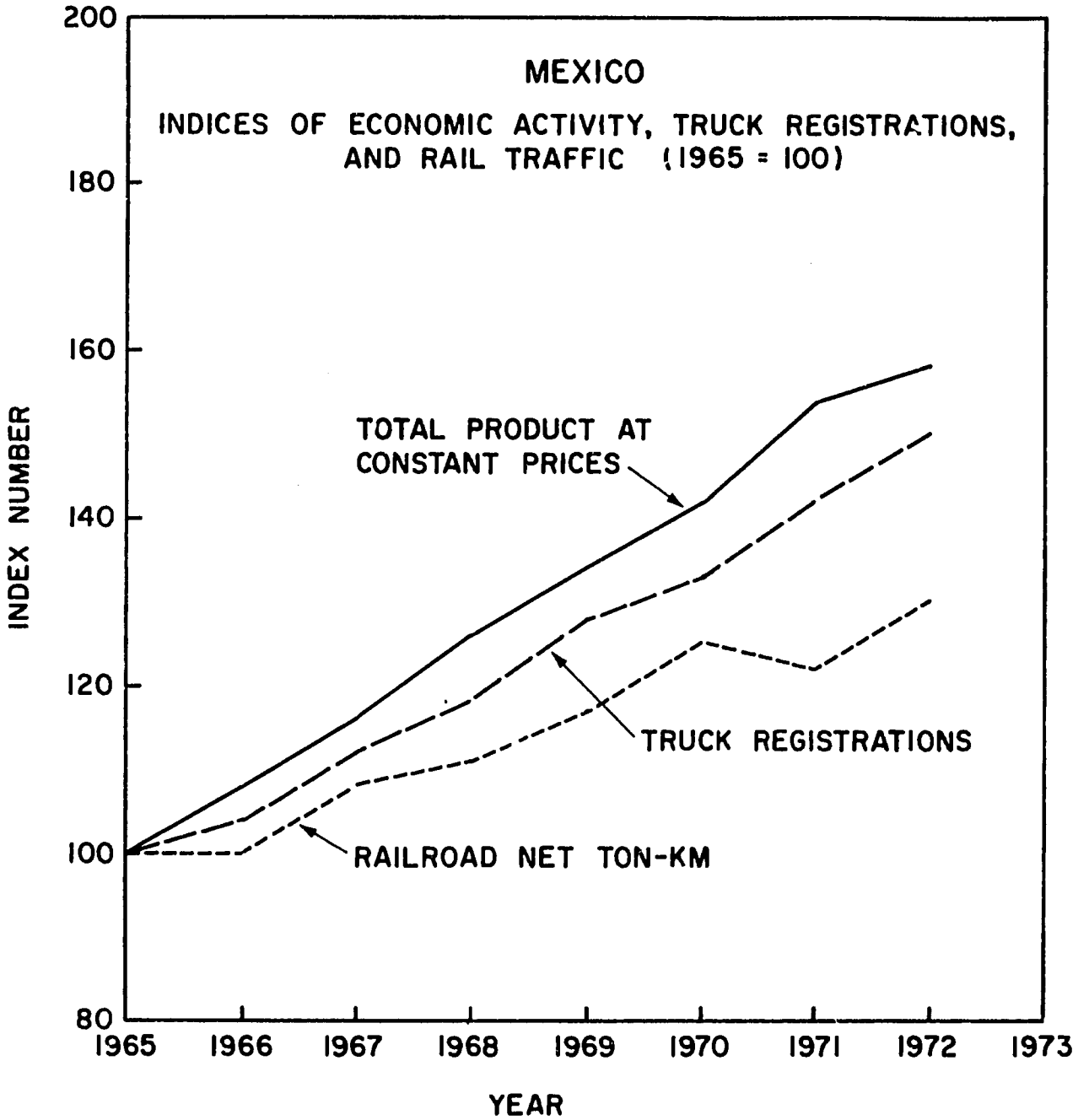

MEXICO
INDICES OF ECONOMIC ACTIVITY, TRUCK REGISTRATIONS, AND RAIL TRAFFIC (1965 = 100)
TOTAL PRODUCT AT CONSTANT PRICES
TRUCK REGISTRATIONS
RAILROAD NET TON-KM
INDEX NUMBER
YEAR
200
180
160
140
120
100
80
1965
1966
1967
1968
1969
1970
1971
1972
1973

FIGURE 7

to international markets. Oil and cement are also major commodities carried by the rail lines. The railroads carry more than a million tons a year of iron and steel, limestone, wheat, soybeans and timber. Figure 8 indicates the trends in volume of the three major commodities from 1970 to 1973 carried by Brazil's railways.

The three chief commodities carried by the Colombian Railways from 1968 through 1973 were wheat, fertilizers and coffee. In Figure 9 one can see that wheat and fertilizer volumes have been rising, while the coffee traffic has declined.

In 1969, prior to the closure of the railway line between Medellin and Cali, 17,000 tons of coffee were shipped from Antioquia to Buenaventura port by railway for export. It may be inferred that much f this tonnage now moves by truck. A considerable amount of coffee was also carried over the highway in 1972 from the Department of Antioquia to the port of Cartegena, almost equalling the quantity of coffee transported to the port of Santa Marta by the Colombian Railway. [14] Inasmuch as coffee accounts for 75 to 80 percent of the country's exports, in terms of monetary value, the impact of these trends on the fortunes of the National Railway can be readily visualized.

The most important commodities carried by Mexico's railroads have been oil, iron ore, cement, fertilizers, limestone and sugar. The railroads carry over two million tons of each of these commodities annually and this traffic has been rising during the past five years with the growth of the economy. Figure 10 gives an indication of the trends of traffic volumes for the three principal commodities transported by rail.

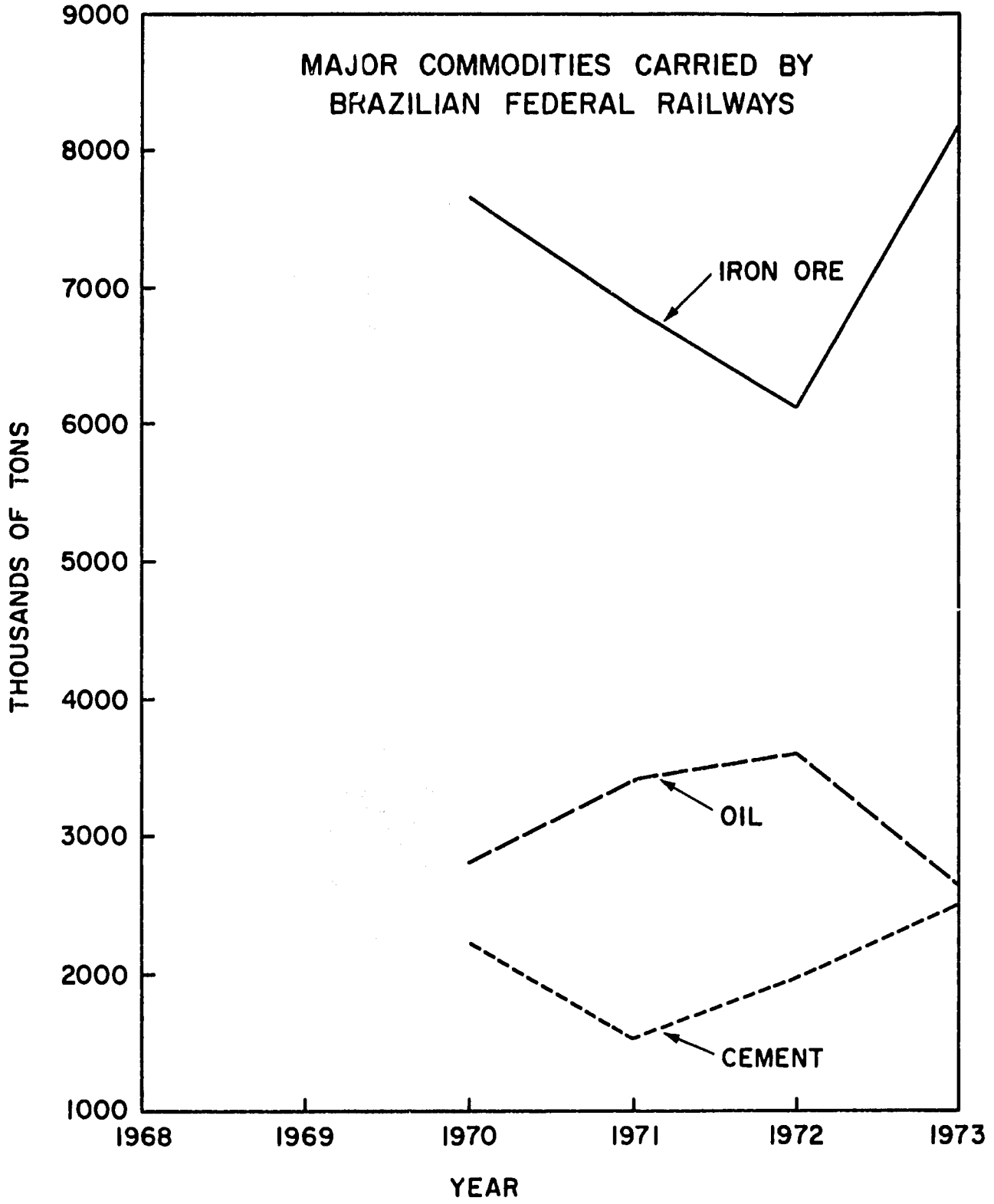

MAJOR COMMODITIES CARRIED BY
BRAZILIAN FEDERAL RAILWAYS
IRON ORE
OIL
CEMENT
THOUSANDS OF TONS
9000
8000
7000
6000
5000
4000
3000
2000
1000
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 8

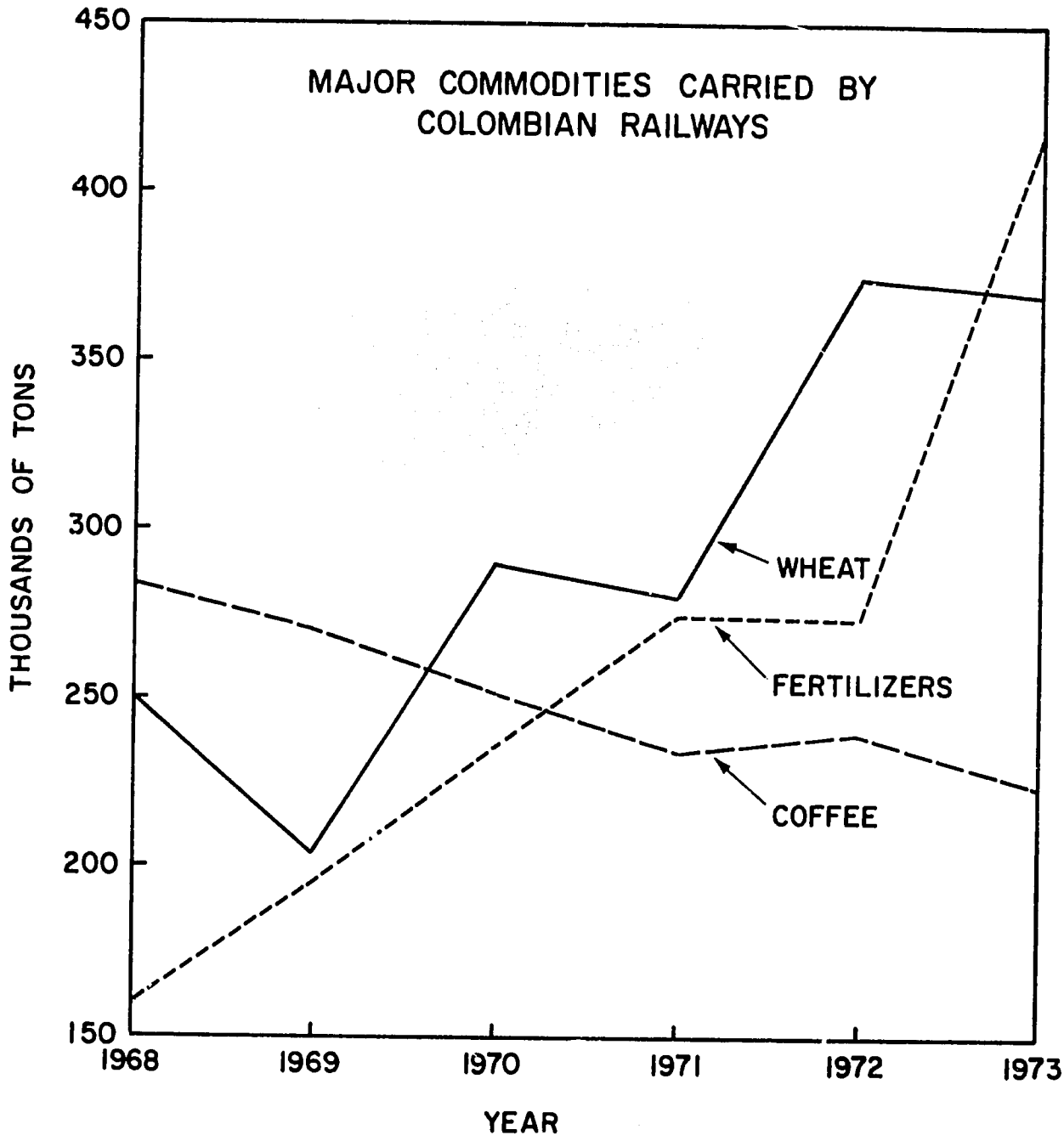

MAJOR COMMODITIES CARRIED BY
COLOMBIAN RAILWAYS
THOUSANDS OF TONS
450
400
350
300
250
200
150
1968
1969
1970
1971
1972
1973
YEAR
WHEAT
FERTILIZERS
COFFEE

FIGURE 9

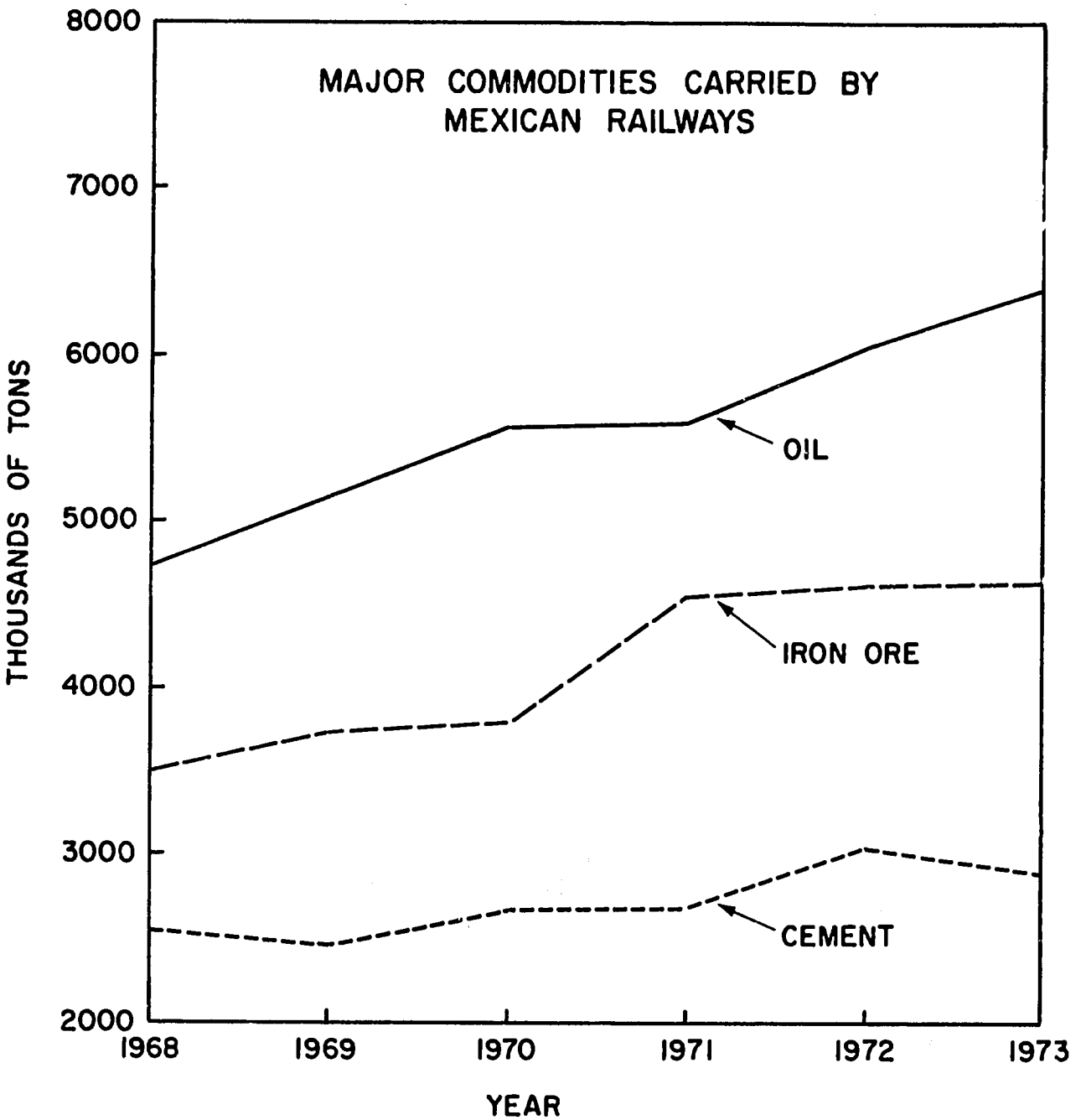

MAJOR COMMODITIES CARRIED BY
MEXICAN RAILWAYS
8000
7000
6000
5000
4000
3000
2000
THOUSANDS OF TONS
OIL
IRON ORE
CEMENT
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 10

B. National Policies Affecting Investment in Transport

In the four countries we studied, the majority of the railroad mileage is nationalized. Nationalized railroads appear to be almost universal in developing countries. Thus, government policies can affect the railroad more directly than in the United States, where the railroads are under private ownership subject to government regulation. Besides economic and safety regulation, governments with nationalized railroads can and do control investment and operating decisions. The profit constraint is not present as suggested by the high operating ratios in the countries studied (see infra). All these incurred large annual deficits, due in part to government policies formulated with social goals in mind. Thus, low cost transportation for people and for the goods of key industries have been more important to some governments than operating a profitable railroad. For this reason, operating ratios can be very misleading.

Railroad rates held down by the government as part of an overall developmental policy may be economically justifiable, but can cause an efficient, well-run railroad to operate at a loss. A wiser strategy to fulfill these social policies could be to reimburse the railroads for losses due to an obligation to charge rates and fares below cost or to absorb expenses not attributable to current operations. For example, if the government wanted people to be able to travel for lower fares than the economic cost of transporting them due to indirect benefits, it should reimburse the railroads on a per ticket basis for the difference between the economic cost and

the subnormal fare. This system is being considered in Mexico.

Government policies on railroad investment differ markedly between countries. Generally, investment in highways has had a higher priority than railway investment. This circumstance leads to deteriorating track and structures, decrepit rolling stock, inefficient yards, large maintenance budgets, and poor service, which forces shippers to rely on other modes. Declining traffic on the railroads due to lack of adequate investment, leads to arguments for "less investment in the railway mode due to lack of traffic" resulting in a vicious circle. A nation can halt this process through a re-evaluation of the role of its railways. Since capital is scarce in developing countries, a careful appraisal of all proposed transport projects is urgently required.

In order for a country to decide on transportation priorities, it must measure the economic costs and benefits in monetary terms. Market prices may not reflect real costs due to the absence of competition in the transportation sector. Subsidization and value-of-service pricing are major problems in this regard, and may necessitate the use of shadow prices. It may also be necessary to make adjustments for foreign exchange rates due to the scarcity of foreign exchange in many countries. In measuring the benefits of a transportation project, it is very important that forecasts be made of other existing and proposed public and private investments in the area. Railroad improvements can result in reduced operating expenses, stimulation of economic development, savings in time for both passengers and freight, accessibility to expanded markets, fewer accidents and reduced loss and damage.

These observations are not intended to convey an impression that investment in a developing country's rail network should have a higher ranking on the scale of priorities than investments in other forms of transportation. It is, however, considered important that transport planning be coordinated with a country's long-term economic goals and that the role of each mode be viewed in the context of those objectives. In the course of this planning phase, the potential of an efficient, well-maintained railway should be evaluated rather than that of a system which may have been unable to function effectively owing to detrimental government policies of one kind or another.

Changes in operating policies can also have a significant effect on the type of railroad investment needed. The specific nature of this relationship will be discussed in Chapter IV.

C. Performance Measures Analysis

In order to evaluate the efficiency of each country's railroad system, a set of relevant performance measures was selected for each sector. They are as follows:

1. Physical Network

- Percent per gauge of total route-km
- Percent electrified of total route-km
- Percent of automatic blocking system of total route-km
- Percent of straight lines of total route-km (Argentina and Mexico only)
- Percent of grades less than 0.5 percent of total route-km (Argentina and Mexico only)

2. Equipment

a. Motive Power

- Percent of steam, diesel and electric locomotives
- Average horsepower per unit
- Ratio of serviceable to total locomotives

b. Rolling Stock

- Average freight capacity per car
- Ratio of serviceable to total freight cars

c. Personnel

- Number of employees per traffic unit (ton-km + pass-km)
- Percent of personnel costs to total costs

3. Operating Characteristics

a. Efficiency

- Net ton-km per route-km (traffic density)
- Net ton-km per train-km (train loading)
- Train-km per route-km (traffic frequency)
- Locomotive units per train
- Freight cars per train

b. Utilization

- Freight car cycle time
- Car-km per serviceable car-day
- Ton-km per serviceable car-day
- Ton-km per loaded car-km
- Ratio of loaded to total car-km

c. Financial Results

- Operating ratio

d. Trend Analysis

A trend analysis for each country was performed with time series

data from 1967 to 1973 involving the following performance parameters:

- Operating ratio
- Net ton-km per route-km
- Net ton-km per serviceable freight car per year
- Number of traffic units per employee
- Net ton-km per train-km

A time series regression equation with origin in 1966, was fitted for the above five performance measures and the results are shown in Table 11. For each of the five measures trended, Y = the parameter in question and X = one year intervals. Estimating the operating ratio of Argentine railroads in 1980, as an example, the equation would be: $Y_1 = 137.857 + 14(5.893) = 137.857 + 82.502 = 220.359$. In Figures 11 to 14 inclusive, the trends for the last three of these measures are graphically displayed.

An analysis of the respective performance measures was conducted utilizing the set of specified indicators, infra. The results applicable to each of the four sample countries' railroad systems has been set forth in Table 12. It will be noted from this table that for the great majority of these indicators, the most favorable performance was recorded for the Mexican system and the least favorable results applied to the railroads of Argentina.

TABLE 11

TREND ANALYSIS

1. Operating ratio (Y_1)

Argentina	$Y_1 = 137.857 + 5.893\ X$
Brazil	$Y_1 = 242.429 - 13.464\ X$
Colombia	$Y_1 = 129.571 - 4.464\ X$
Mexico	$Y_1 = 131.286 + 6.286\ X$

2. Net ton-km per route-km (Y_2)

Argentina	$Y_2 = 291.143 + 9.571\ X$
Brazil	$Y_2 = 352.571 + 28.714\ X$
Colombia	$Y_2 = 302.857 + 8.214\ X$
Mexico	$Y_2 = 927.571 + 56.571\ X$

3. Net ton-km per serviceable freight car (Y_3)

Argentina	$Y_3 = 136.430 + 15.964\ X$
Brazil	$Y_3 = 269.143 + 21.179\ X$
Colombia	$Y_3 = 172.857 + 4.285\ X$
Mexico	$Y_3 = 744.286 + 21.929\ X$

4. Number of traffic units per employee (Y_4)

Argentina	$Y_4 = 172.857 + 2.464\ X$
Brazil	$Y_4 = 144.714 + 5.857\ X$
Colombia	$Y_4 = 115.143 + 3.357\ X$
Mexico	$Y_4 = 293.429 + 19.750\ X$

5. Net ton-kms per train-km (Y_5)

Argentina	$Y_5 = 281.857 + 8.536\ X$
Brazil	$Y_5 = 293.857 + 18.643\ X$
Colombia	$Y_5 = 101.143 + 23.571\ X$
Mexico	$Y_5 = 758.857 + 20.286\ X$

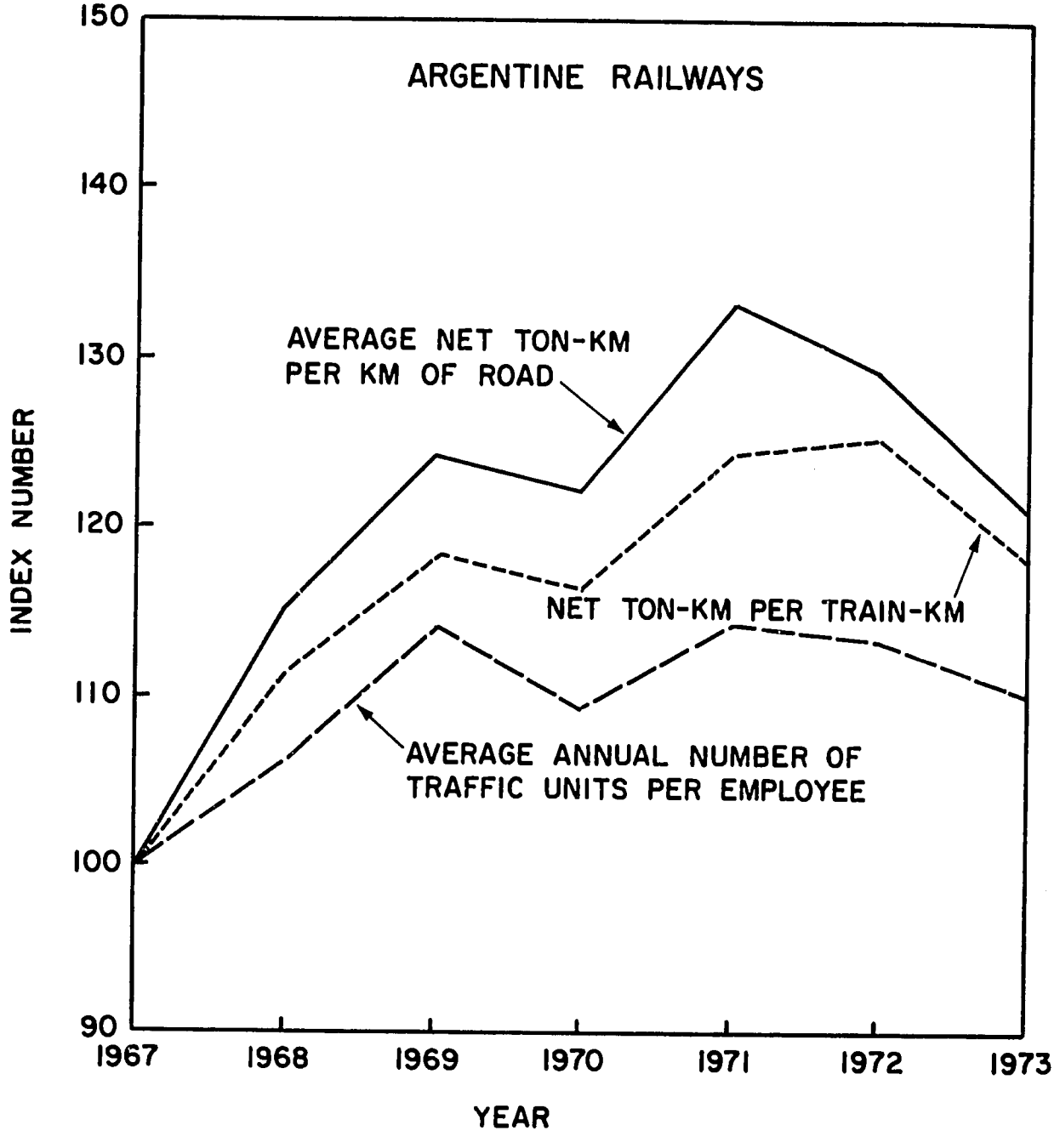

ARGENTINE RAILWAYS
AVERAGE NET TON-KM PER KM OF ROAD
NET TON-KM PER TRAIN-KM
AVERAGE ANNUAL NUMBER OF TRAFFIC UNITS PER EMPLOYEE
INDEX NUMBER
150
140
130
120
110
100
90
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 11

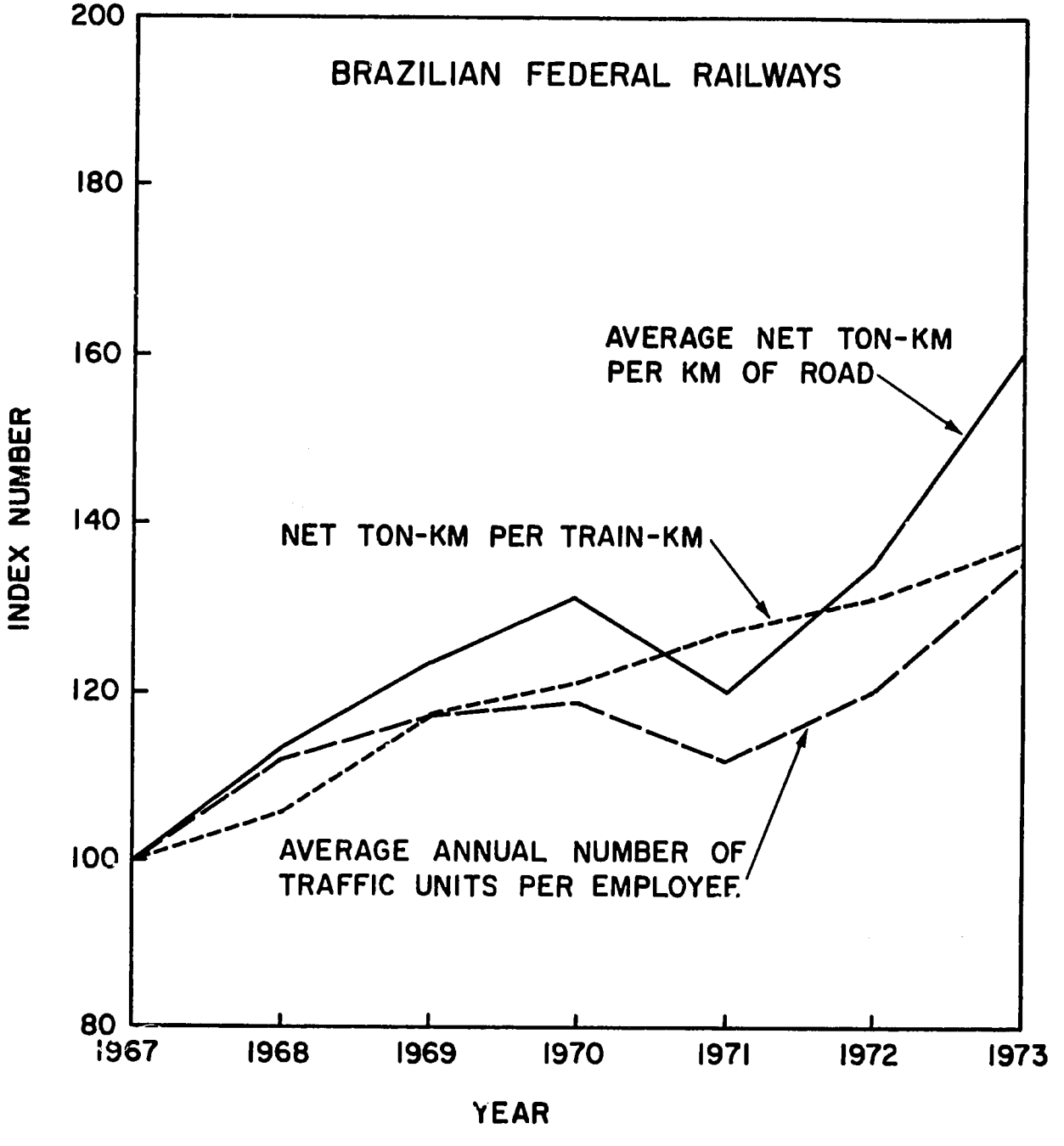

BRAZILIAN FEDERAL RAILWAYS
AVERAGE NET TON-KM PER KM OF ROAD
NET TON-KM PER TRAIN-KM
AVERAGE ANNUAL NUMBER OF TRAFFIC UNITS PER EMPLOYEE
INDEX NUMBER
200
180
160
140
120
100
80
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 12

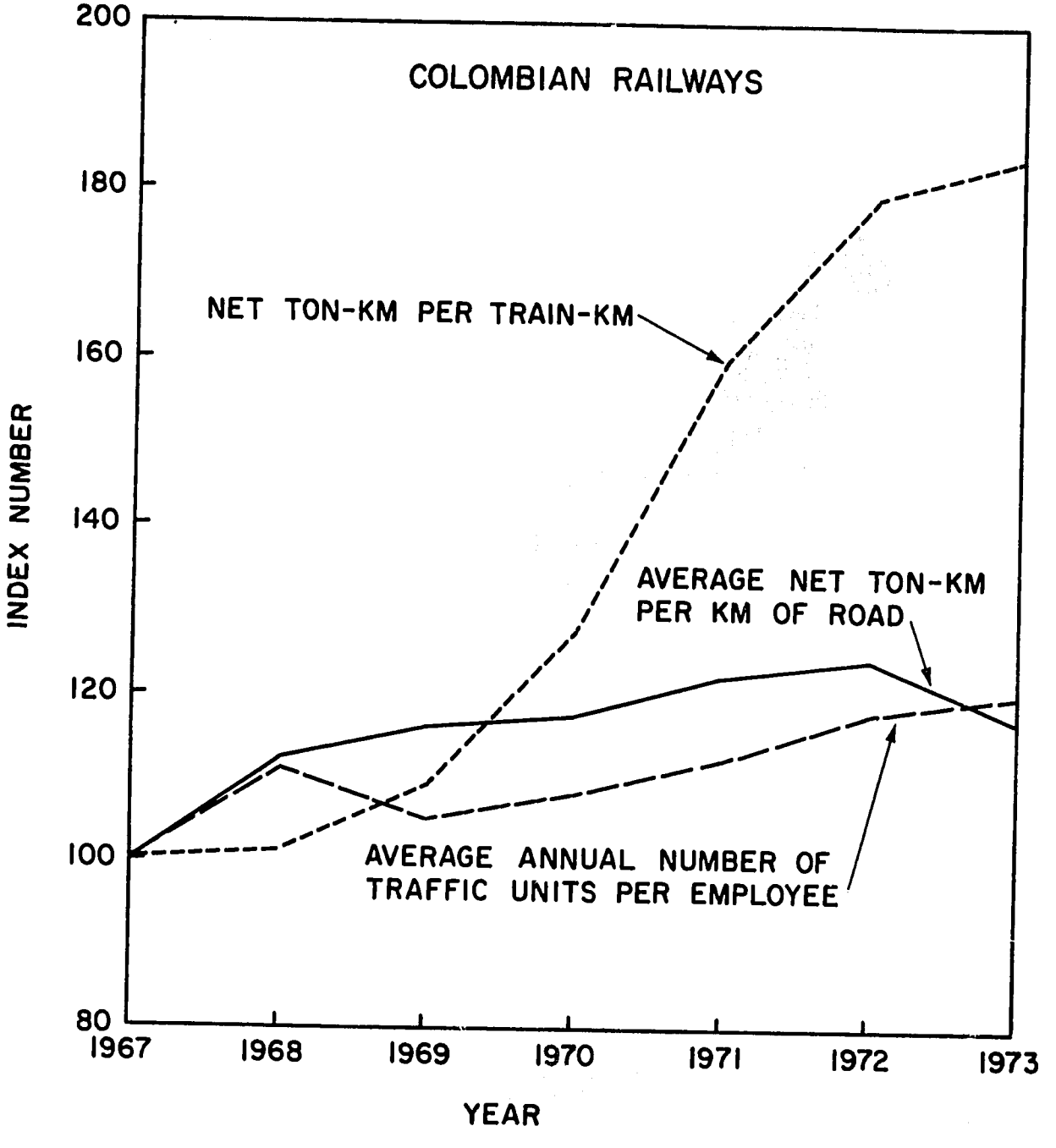

COLOMBIAN RAILWAYS
NET TON-KM PER TRAIN-KM
AVERAGE NET TON-KM PER KM OF ROAD
AVERAGE ANNUAL NUMBER OF TRAFFIC UNITS PER EMPLOYEE
INDEX NUMBER
200
180
160
140
120
100
80
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 13

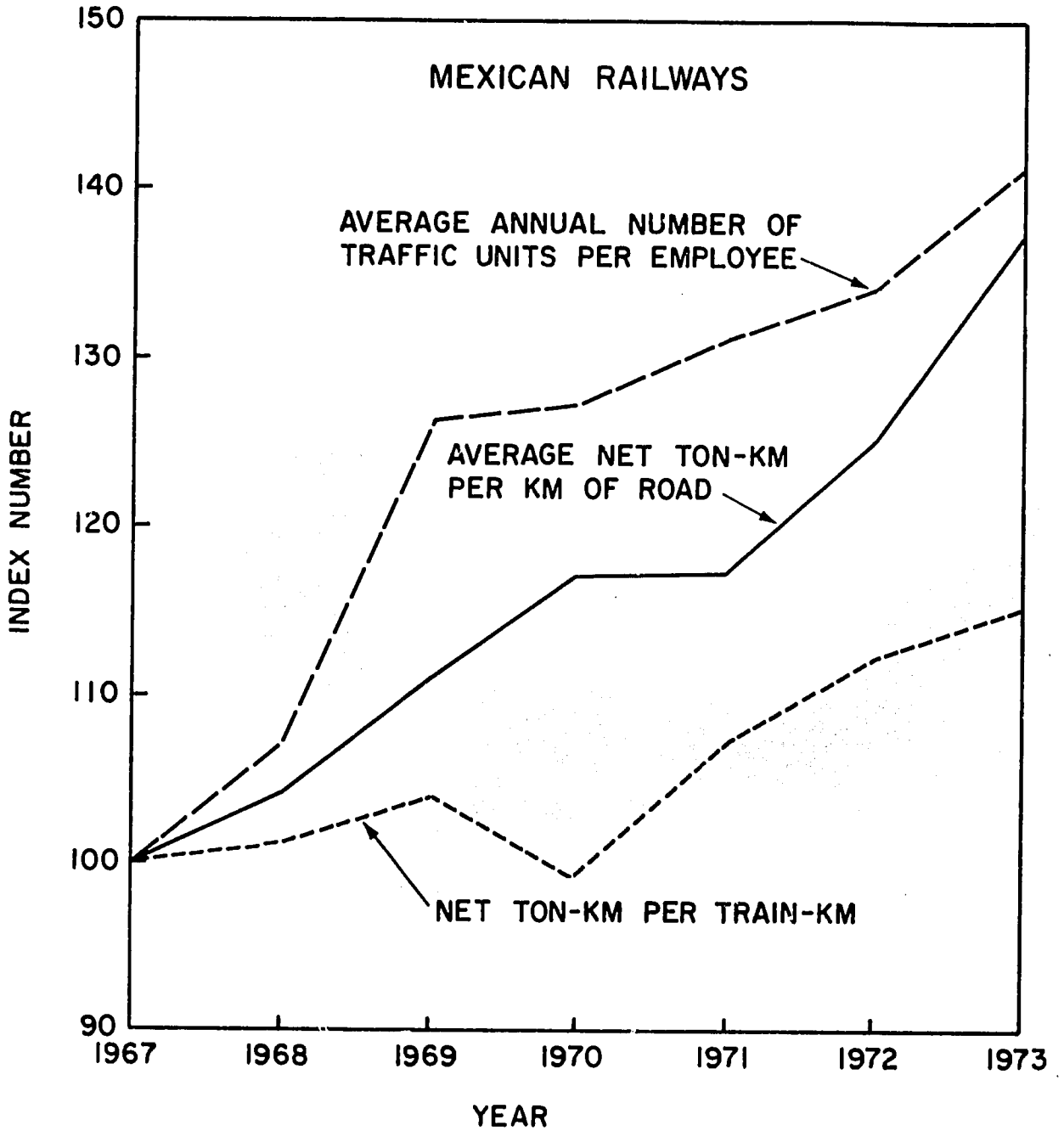

MEXICAN RAILWAYS
AVERAGE ANNUAL NUMBER OF TRAFFIC UNITS PER EMPLOYEE
AVERAGE NET TON-KM PER KM OF ROAD
NET TON-KM PER TRAIN-KM
INDEX NUMBER
150
140
130
120
110
100
90
1967
1968
1969
1970
1971
1972
1973
YEAR

FIGURE 14

TABLE 12

PERFORMANCE MEASURES: 1973

	ARGENTINA	BRAZIL	COLOMBIA	MEXICO
Physical Network				
Percent of total route-km				
1.676m gauge	58.4	---	---	---
1.600m gauge	---	6.9	---	---
1.435m gauge	7.7	---	---	94.5
1.000m gauge	33.9	92.2	---	---
0.914m gauge	---	---	100.0	5.5
0.760m gauge	---	0.9	---	---
Percent of route-km electrified	0.3	4.4	---	0.5
Percent of route-km with automatic blocking system	0.1	0.4	---	3.5
Percent of route-km in straight line	89.6	NA	NA	25.8
Percent of route-km with grades less than 0.5 percent	77.4	NA	NA	25.1
Equipment				
Percent of total locomotives				
steam	49.1	8.1	---	0.2
diesel	50.9	86.7	100.0	99.5
electric	---	5.2	---	0.3
Average horsepower (HP)				
diesel	1,410	1,060	1,200	1,920
electric	---	2,090	---	2,555
Ratio of serviceable/existing locomotives				
steam	0.53	0.61	---	0.75
diesel	0.66	0.88	0.81	0.81
electric	---	0.85	---	0.66
Average capacity of freight cars (tons)	35	34.0	34.0	50.2
Ratio of serviceable/existing freight cars	0.76	0.92	0.80	0.95

PERFORMANCE MEASURES: 1973 (continued)

	ARGENTINA	BRAZIL	COLOMBIA	MEXICO
Personnel				
Employees per million traffic units (ton-km + pass-km)	10.9	7.8	7.2	3.6
Percent of personnel costs over total costs	74.8	57.2	63.1	59.3
Financial Results				
Operating ratio	185	157	110	176
Operating Characteristics				
Efficiency				
Net ton-km per route-km	329,500	588,000	340,000	1,362,000
Net ton-km per train-km	321	425	264	917
Train-km per route-km	1,026	1,383	1,292	1,486
Locomotives per train	2.5	3.3	2.5	3.2
Freight cars per train	21	20	16	34
Utilization				
Approximate cycle time	20.2	9.7	15.2	7.8
Car-km per serviceable car-day	54.7	59.7	40.8	99.4
Ton-km per serviceable car-day	819	1,265	679	2,663
Ton-km per loaded car-km	24.3	30.7	24.6	41.0
Ratio of loaded to total car-km	0.62	0.69	0.68	0.65

IV. ESTIMATION OF DEMAND, USE OF SCREENING MODELS AND OTHER QUANTITATIVE METHODS

A. Prospective Demand for Railroad Freight Service in the Next Decade

In order to make wise decisions on future investment policies for the railroad network, predictions are needed on the growth (or decline) of rail traffic. One should not compare the results, *a priori*, of an investment with the situation before the investment; rather, one should compare the anticipated results with estimates of the situation if there had been no investment.

In order to evaluate different alternatives through the use of screening models, we made forecasts of future traffic in the four sample countries studied. The forecasts were made by considering indexes of their rail traffic in net ton-kilometers (base year 1965) as a function of their indexes of total product at constant prices, agriculture production, and mineral production, respectively, for the years 1967 through 1972 inclusive. Statistics were taken from the U.N. Statistical Yearbook. [31] It was assumed that a linear relationship existed, the basic equation taking the form:

$$Y = a + bP + cA + dM + u \qquad (1)$$

where Y represents net ton-kilometers of rail freight

a equals a constant

P represents total domestic product at constant prices

A represents agricultural product at constant prices

M represents mineral product at constant prices

b,c,d represent coefficient values

u represents the residual causal factors not explained by the specified independent variables.

The result obtained from the equation by a stepwise ordinary least squares regression containing 24 observations (6 years' data for four countries) is shown in equation (2):

$$\hat{Y} = 23.492 + \underset{(0.105)}{0.407P} + \underset{(0.131)}{0.371A} + \underset{(0.033)}{0.024M} \qquad (2)$$

Standard errors are shown under the coefficients to which they apply. The F ratio is 15.314, which is significant at the 99 percent level for three independent variables and 19 degrees of freedom: The R^2 is .696 of which .538 has been accounted for by total product at constant prices. The standard error of the estimate equals 8.247 Equation (2) indicates that the strongest independent variable affecting railroad ton-kms has been the level of total domestic product, where an increase of one unit of P would produce a 0.407 unit increase in rail freight traffic, <u>cateris paribus</u>. The coefficients for total domestic product at constant prices and agricultural products at constant prices are statistically significant, being twice the value of their respective standard errors; mineral products' coefficient is not statistically significant.

The above specified variables, viz: total product at constant prices, agricultural product at constant prices, and mineral product at constant prices were projected by linear extrapolation for the years 1980 and 1985. Their predicted values for these five-year intervals were entered into equation (1) to predict the level of rail freight traffic for the years specified. The findings from this analysis are presented in Table 13. These predictions require

further refinement in order to include level of service variables which would facilitate an evaluation of different investment strategies. However, they are sufficient for applying the screening models developed at M.I.T. [2] In the next section, the use of these screening models when applied to the railroads of developing countries is reviewed.

TABLE 13

PREDICTED GROWTH OF RAIL TRAFFIC

(In Millions of Net Ton Kilometers)

Year	1973	1980	1985
ARGENTINA	13,116	16,766	18,358
BRAZIL (Federal R.)	14,149	18,240	21,213
COLOMBIA	1,168	1,796	2,054
MEXICO	27,130	30,943	35,129

B. The Modeling Approach: The Use of Screening Models

(This section has been copied almost verbatim from "Progress Report on the Study of Methodologies for Developing and Evaluating Effective Rail Networks". [25]

Although opportunities for network rationalization include such diverse possibilities as line abandonments, yard consolidations, renovation and modernization of the network, concentration of through traffic on a small number of lines, changes in work rules, and revision of car service rules, the goals of rationalization can be simply stated:

1. Improve service quality to allow more efficient use of resources by current and potential rail shippers.
2. Improve rail operations to allow more efficient use of resources by railroads.
3. Improve inter-modal coordination to allow more efficient use of the nation's transportation resources.

Each of many alternatives for creating better rail networks must be evaluated with respect to these three goals before the rail industry can develop an effective strategy for upgrading its performance. To do this, planners and top management must have estimates of the effects of proposed alternatives on rail costs, service, and revenues. For any single alternative, of course, planners can use existing models such as the AAR's network simulation model to determine economic and operating feasibility. Unfortunately, such models require extensive data preparation, expensive blocks of computer time, and extended periods of time, thereby making it impractical or impossible to evaluate any large set of alternatives during a reasonable time period at a reasonable expense. Planners must use an explicit or implicit methodology to select a small set of the most promising alternatives for intensive analysis using a sophisticated model. Although a planner thoroughly familiar with a specific network may often be able to identify the best alternatives, more often he will benefit from the use of one or more simple models of rail costs or operations as an aid to his judgment when screening a large number of alternatives. This is certainly true when nobody has experience with the entire region being studied,

when there are major technological advances, or when substantial changes in operating policies are contemplated. In these situations, experience in rail operations must be supplemented by theoretical insight into rail production functions and cost functions.

Screening models provide planners with a means to examine alternatives in order to eliminate the least promising or, viewing the same process from a different perspective, to select the most promising of a large set of alternatives. The distinction between screening models and other models depends largely on the way they are used in an evaluation process; the screening model helps narrow the range of options analyzed by a more powerful or more discriminating model. Depending on the time and resources available, a particular model might be used either in the final step of the evaluation process or as a screening model for a more complex model.

A screening model's value increases as it becomes easier, cheaper or faster to use and decreases as it becomes less discriminating or less reliable. Consider a planner faced with N mutually exclusive investment options. With a powerful simulation model he may be able to obtain excellent estimates of the impacts of each option at a unit cost of C or a total cost of NC. If he is confident that the optimum choice will be among the pN ($p<1$) best as evaluated by a simpler method costing only kC per option ($k<1$), then he can simulate these pN options at a cost of (kC)N for the screening process plus C(pN) for the simulation for a total cost of (k+p)NC. So long as (k+p) is less than 1, the screening process will be less expensive. Of course, if the planner does use a screening process, he runs the risk that the best option will not

be among the pN selected for further analysis. Increasing p reduces this possibility, but raises the total cost; budgetary constraints and past experiences must guide the planner. The value of the screening process is most evident when the most sophisticated models are too costly or too time consuming. If screening models are available, the planner has an alternative to using his or others' experience and judgment to limit the scope of his investigation.

An example of the application of a screening model to the estimation of a railroad's motive power requirements, also derived from the "Progress Report", op.cit., is presented in Appendix A.

C. Operational Requirements Needed to Meet the Estimated Traffic Demand

Given our predictions for future demand and the appropriate screening models developed, we can look at future requirements of the railroad network, on the basis of present performance measures and estimate how different operating procedures would affect future operational requirements. One of the results of past work on railroad rationalization in the United States has shown that, in evaluating possible investments, a systems analysis approach to the problem must be taken. [24] For example, when there is a shortage of freight cars, it might seem obvious that an investment in more freight cars is required; however, there are a number of other possible solutions which may have a lower net present cost, especially in capital starved countries. Increases in car utilization, average car capacity, percent of cars loaded, percent of cars serviceable, and average car speed are other alternatives to the purchase of new freight cars.

Using the locomotive power requirements screening model described in Appendix A, and assuming that performance measures would remain constant, we calculated the locomotive requirements for the next five and ten years, respectively. The screening model used was adapted for data on an annual basis as available, and is shown below:

$$L = \frac{NV}{8760\ U_e SM} \qquad (3)$$

L = the required number of locomotives

N = the average number of locomotives per train

V = annual freight car-km

8760 = number of hours in a year

U_e = measure of locomotive utilization expressed in the fraction of time that the locomotives are in train service

S = average train speed

M = average train length

Performance measures are from 1973. [22] The relevant parameters for each country can be found in Table 14. Table 15 provides estimates of future requirements assuming constant performance measures and indicates that there will be a growing need for locomotives in the coming decade as old locomotives are retired and the railroads grow to meet an expanding economy.

A freight car requirements screening model was also applied to the four countries studied based also on assumed constant performance measures.

The screening model is:

$$F = \frac{T/365}{U_f KPM} \qquad (4)$$

TABLE 14

PARAMETERS FOR ESTIMATING FUTURE LOCOMOTIVE REQUIREMENTS

	N Locomotives Per Train	V Car-Km	U_e Percent of locomotive time in service	S Km/hr.	M Cars/train
ARGENTINA	2.47	600,378,000	24.07	31.7	21.44
BRAZIL	3.27	667,087,000	58.04	17.3	20.06
COLOMBIA	2.53	70,133,000	46.81	19.4	15.82
MEXICO	3.16	1,012,706,000	47.95	22.8	34.25

TABLE 15

LOCOMOTIVE REQUIREMENTS ASSUMING CONSTANT PERFORMANCE MEASURES

Year	1973[1]	1973[2]	1980	1985
ARGENTINA	2498	1501	1919	2064
BRAZIL	1439	1410	1818	2127
COLOMBIA	174	168	259	289
MEXICO	1207	1643	1874	2127

[1]Actual number

[2]Requirements according to screening model-equation no. (3).

where

F represents the number of freight cars required

T represents the net ton-kms transported

U_f represents car capacity utilization

K represents average car capacity

P represents the ratio of loaded car-km to total car-km

M represents the car-km per serviceable car-day

From this formula we can estimate without difficulty the effects on rolling stock of changes in car capacity, car utilization, percent of cars loaded, and average speed. Table 16 lists the applicable parameters for this model, while future freight car requirements have been estimated in Table 17. Projected net ton-kilometers for each country's system have been listed in the first section of this chapter.

TABLE 16

PARAMETERS FOR ESTIMATING FUTURE FREIGHT CAR REQUIREMENTS

	U_f Average Percent of Capacity Utilized	K Tons	P Percent of Cars Loaded	M Km Per Day
ARGENTINA	69.5	35	61	54.73
BRAZIL	90.4	34	69	59.67
COLOMBIA	72.4	34	68	40.76
MEXICO	81.7	50	65	99.39

TABLE 17

FREIGHT CAR REQUIREMENTS ASSUMING CONSTANT PERFORMANCE MEASURES

Year	1973[1]	1973[2]	1980	1985
ARGENTINA	57,853	43,900	56,593	61,967
BRAZIL	33,439	30,632	39,489	45,926
COLOMBIA	5,893	4,690	7,212	8,248
MEXICO	29,416	27,923	30,943	35,129

[1]Actual number

[2]Requirements according to screening model-equation no. (4).

V. CONCLUSIONS

A. General Findings

The research underlying this report has dealt with the railroad systems of four Latin American countries, each in a different stage of development. The inevitable consequence has been the finding of significant differences in the role of each rail network in the overall economy, in the degrees of utilization of the network and in comparative measures of operational and fiscal performance.

In terms of similarities among the four systems, it is important to note that all are owned and operated by their respective national or regional governments. This has made them instruments of governmental policy as respects development, balance of trade, employment regulations and other political influences. Such financial indicators as operating ratios and net income or deficit must be judged accordingly; the concept of profit maximization has not been found to be the most important objective which these Latin American railroad managements have sought to attain. This circumstance makes comparisions with the financial results of privately owned United States railroads inappropriate.

As has been demonstrated in Chapter III, the operating ratios (operating expenses divided by operating revenues) of the sample railways have varied considerably, yet all have exceeded 100, meaning that annual operating expenses have been greater than annual operating revenues. This could be caused by insufficient control of expenses, inadequate levels of freight rates and passenger fares or a combination of both.

As long as the railways of these countries are restrained by external policies from establishing a reasonable relationship between revenues and costs, annual losses will be reported. Even though the governments involved cover the deficits out of general tax funds, a false image as to the worth of the railway system is likely to prevail and morale of managements and employees alike will suffer.

This study has been confined to railway freight economics and operations and virtually no examination has been made of the passenger services. Except for a substantial short-haul communter volume in Buenos Aires, Rio de Janeiro and Sao Paulo, the carriage of passengers has not proved to be a factor of great magnitude in any of the countries reviewed and there appear to be no indications of a change in this situation. In fact, with the exception of Mexico, the trend in passenger volume has been consistently downward.

Projections of future freight business have been made based on extrapolations of past growth of railway traffic. The longer the time interval covered by extrapolation, the greater becomes the margin for error. According to Table 13 in Chapter IV, freight kms handled by the railways in 1985 should show gains above the level actually transported in 1973 as follows:

Argentina:	+40%
Brazil Federal:	+50%
Colombia:	+76%
Mexico:	+30%

These projected increases are highly dependent on factors, both within and beyond the control of the respective governments and include, inter alia, national and world economic conditions, weather, political developments, government investment decisions affecting the various transport modes, technological changes in industry, agriculture and transport, discovery and exhaustion of mineral resources and other factors. The railways of Brazil and Mexico have fared reasonably well in most of these areas, while those of Argentina and Colombia have not.

It is important that each country carefully calculate the benefits and costs associated with the continued maintenance of its railway network. A program of rationalization should be devised whereby essential components will be upgraded and modernized to improve their efficiency, utilization and level of service. At the same time, unessential segments should be scheduled for phasing out of the network altogether, rather than have them slowly disintegrate while deficits increase and service deteriorates. It is assumed that, in most cases, alternative forms of transport can be substituted for railway lines selected for abandonment without serious impairment of the economies of affected communities. [32]

In terms of transfer of technology, one specific example of the research activities of the "Railroad Group" in M.I.T.'s Civil Engineering Department is cited as an indication of opportunities for such transferences.

A chronic problem manifested among each of the sample Latin American railway systems has been a relatively poor utilization of their fleets of freight cars (see Chapter III). An important

feature of the M.I.T. studies in railroad operations and economics in the United States has consisted of a test program conducted on the Southern Railway System for the purpose of validating the findings of the research group regarding the impact of improved service reliability on overall railroad performance. The relationship between reliability and freight car utilization had been predicted to be both positive and significant; the actual test on the Southern gave strong support to this forecast.

As may be observed in Table 18, increases in service reliability achieved during the test were accompanied by reductions in trip time and in cost savings equaling or exceeding a priori expectations. By making appropriate adjustments in their scheduling and operating procedures, Latin American railroads should be able to realize proportionate benefits through better use of their car supply and operating cost reductions.

A list of reports emanating from the M.I.T. program of research in railroad operations and economics has been provided in Appendix B.

B. Specific Findings

Conclusions based on this research project which apply primarily to the individual railway freight networks of each of the Latin American countries included in our investigation are set forth below:

1. Argentina

There has been an apparent neglect of Argentina's railways in recent years, as indicated in our examination of their freight performance measures. The railway's share of the freight transport

TABLE 18

Summary of the Test Program

Alternative		Cars/Day	Increase in Reliability	Decrease in Trip Times	Monthly Decrease In Cost
1. Operate run-through trains between D and E	Predicted	200	22%	16 hours	$15,000
	Actual	180	14%	19 hours	$15,000
2. Monitor industrial switching near A	Predicted	60	10%	18 hours	$ 5,000
	Actual	40	15%	21 hours	$ 6,000
3. Allocate more power and revise local operating procedures for agricultural traffic from K	Predicted	68	25%	18 hours	$ 4,000
	Actual	72	14%	18 hours	$ 6,000
4. Move through cars only on the runthrough train from F to E *	Predicted	40	10%	12 hours	$ 2,500
	Actual	40	2%*	10 hours*	$ 2,000*
5. Revise train schedules to reduce unreliable connections at D	Predicted	200	10%	4 hours	$ 4,000
	Actual	210	**	**	**

* This improvement did not result from the test program.
** Comparable results are not available

market has been declining in consequence of this neglect and there have been no signs of a reversal of this trend.

Among the performance measures of the Argentine railways, which may be attributed to deficiencies in management or government indifference or both, are the following:

(a) Equipment gives evidence of being in bad condition.
(b) Average horsepower of locomotive fleet is low.
(c) A high percentage of steam locomotives continues in service.
(d) Average capacity of freight cars is low.
(e) Annual personnel costs exceed total revenues.
(f) Traffic density, frequency of service and capacity utilization are low.
(g) Cycle time between loading of freight trains is low.
(h) Average length of freight trains is low.
(i) Operating ratios are high and the trend is upward.
(j) In common with Brazil, Argentina's railways suffer from the lack of a uniform gauge which inhibits traffic flows between areas served by lines of different gauges.

2. Brazil

The principal problems which have been found to prevail on the Brazilian railways are as follows:

(a) The railroads' market share of total goods movement has been declining.
(b) Average low horsepower of locomotives prevents economical train lengths.
(c) Productivity of personnel employed on the railways is relatively low.
(d) Traffic density and frequency of service are indicators of under-utilization of infrastructure and equipment.
(e) Roadbed is not maintained to satisfactory standards of safety leading to frequent accidents.
(f) Both operating ratios and deficits are trending upward indicating that charges are too low or costs are too high.
(g) Serious complications arise from the non-uniformity of gauge.

3. Colombia

(a) The National Railway suffers from the rugged terrain which it must traverse. For example, between the valley of the Magdalena River and the savanna on which Bogota is situated, a 4 percent grade against the prevailing loaded movements creates serious operating problems and high expenses.

(b) The narrow gauge (.914 km) limits capacity and prevents heavy loading of bulk commodities.

(c) Sections of the line have not been properly maintained and this circumstance, together with relatively frequent landslides, have resulted in frequent line interruptions and an excessive number of derailments.

(d) A large imbalance in freight traffic is experienced, leading to a high proportion of empty car-miles.

(e) Highway alignments between major points of origination and termination of goods transport are usually more direct than corresponding rail routes, providing trucks with an important service advantage.

(f) Freight cars are either moved too slowly or detained for loading or unloading producing an average car cycle time of 18 days.

(g) In contrast to the situation observed in other Latin American countries, Colombia Railway's operating ratio has been declining during the most recent years for which data are available.

4. Mexico

(a) Most sections of the National Railway are maintained to standards equaling or exceeding those of many successful U.S. railroads.

(b) The small fleet of electric locomotives used on the line between Mexico City and Vera Cruz via Cordoba appears to be poorly maintained.

(c) Freight rates have been frozen between 1959 and December 1974, when a 30 percent increase was authorized by the government. A high and increasing operating ratio may be attributed, in part, to the failure of freight rates to keep pace with rising costs.

(d) Since 95 percent of route-miles of all Mexican railroads conform to the standard gauge (1.435m), relatively large and heavy loads can be accommodated. Direct interchange of equipment with U.S. railroads takes place at numerous border crossings between Matamoros near the Gulf of Mexico and Mexicali in southern California, permitting

through shipments to be made between points in Mexico and the U.S. without a transfer in route.

(e) Operating expenses are adversely affected by arrangements requiring the railways to assume burdensome costs incurred in accordance with labor-management agreements covering conditions of employment and retirement benefits.

C. Findings Applicable to Developing Countries Throughout the World

It is somewhat presumptuous to attempt to apply the results of an investigation of four countries' railroad systems, all in a relatively proximate geographic area, to developing regions in other continents, notably Africa and Asia. Differences between such regions and the sample countries of Latin America included in this study probably outweigh the similarities, thereby making generalizations of extremely limited value.

There appear to be, however, several observations emerging from our review of the Latin American transport scene which have relevance to most countries in a developmental stage, regardless of their location. These are itemized below:

1. Planning for an overall transport network should be undertaken before investment funds are actually committed for construction. Cost/benefit studies should be coordinated so decisions as to the type and configuration of the network can best serve the needs of the area.

2. Investment in transport infrastructures should be based on a minimum amount of duplication of services. Underutilization of existing facilities has been a widespread problem for those countries in our study.

3. Once a particular mode has been selected to provide transportation service in an undeveloped or underdeveloped area, that mode should receive sufficient funds to assure proper

maintenance of its right-of-way and equipment.

4. The character of goods moving in each direction might best be transported by different modes, although considerations regarding the advantages of attaining a reasonable bi-directional balance of commodity flows should precede any use of scarce economic resources to invest in competitive route structures.

5. In the case of railroads, the implementation of planning decisions and responsibility for the consequent results should be assigned to the same individuals. Financial accounting should be organized to show clearly the actual operating profit or loss. Payments to redundant or retired personnel and other extraneous expenses dictated by government policies should not be permitted to obscure the basic performance of the railways.

6. Prices charged by the railways should, as nearly as possible, reflect the costs of transporting the traffic in question. Sub-normal rates or fares on particular traffic flows established to promote national or regional development should be normalized by a governmental grant or subsidy to compensate the railroad for these reduced charges.

7. To the extent permitted by available resources, any railway system operating in an underdeveloped area should maximize its use of technological improvements adopted by railways in Europe, Canada and the United States. These would include, inter alia, centralized traffic control, hump yards for classifying freight trains, unit trains, trailers on flat cars, electrification, and special types of equipment designed for the efficient transport of particular commodities.

8. Creation of railway systems of uniform gauge within a country and between a country and its neighbors should be a matter of the highest priority. Transfer of lading at

gauge breaks is a primary source of delays, unreliability and diversion of freight from railroads to competing modes. A gauge of no less than 1.435m is recommended to take advantage of the railroad's capability to carry large, heavy loads more efficiently than most competitive services.

9. Arrangements should be made for the training of persons in top and middle management positions on railroads of developing countries in the techniques of modern business. Such training should encompass the range of functions of the transport firm and should be a prerequisite for appointment to key management positions.

D. Suggestions for Further Research

This study has been organized as an exploratory review of the role of the railroad network in developing countries. The investigatory methodology involved the selection of one major geographic area -- Latin America -- and concentration on four countries in that area with diverse topographies, economies and transport network configurations. The staff engaged in this project have identified many of the problems affecting the railroad services of the four countries viewed as a whole, and individual problems experienced by one country or a specific segment of a country's network.

The enumeration of these problems throughout the preceding chapters and sections of this chapter disclose many situations where corrective measures are both advisable and feasible within constraints imposed by budgeting and policy considerations. It is our recommendation that intensive study be given to the implementation of changes which will both enhance the role of the railroads and facilitate the

economic well-being of the involved nations.

As a suggestion for further research, it is proposed that a detailed study be undertaken of the commodity flows and associated transport networks of a single developing country. Concentration of this kind would afford a research team at M.I.T. a valuable opportunity to gain an awareness and understanding of specific relationships existing between transport and other sectors of the economy in the developmental process. It would, hopefully, enable the researchers to collaborate with university faculty and students in the country selected for such a project, thereby utilizing the inherent advantages of each group to produce a far more comprehensive set of procedures and findings than either could achieve on its own.

It is recommended that a program embodying the above-mentioned characteristics be given favorable consideration in the forthcoming academic year.

APPENDIX A

SCREENING MODEL FOR PREDICTING FUTURE LOCOMOTIVE REQUIREMENTS

As a first approximation, the number of locomotive units required to move a specified traffic volume over a given line is:

$$L = \frac{NVD}{168\ U_\ell SM}$$

where L = the required number of locomotives.

N = locomotive units/train.

V = weekly cars handled, loaded and empty.

D = length of line.

168 = the number of hours in a week.

U_ℓ = efficiency of locomotive utilization expressed as the fraction of time that the locomotives are in train service.

S = average train speed.

M = average train length.

<u>Proof</u>: a) line haul time = $D/S = T$.

This determines the number of cycles each locomotive consist will make in a week:

$$\text{b) cycles/week} = \frac{168\ U_\ell}{T} = \frac{168\ V_\ell S}{D} = W.$$

When combined with average traffic volumes V and train length M, cycles/week W determines the number of locomotive consists required.

c) trains/week = $V/M = R$.

$$\text{d) } C = R/W = V/MW = \frac{VD}{168\ U_\ell SM}.$$

Therefore e) $L = NC = \frac{NVD}{168\ U_\ell SM}$.

As shown in formula (A-1), power requirements are proportional to the number N of units per consist and inversely proportional to train length M. If the number of units used is actually governed by a desired horsepower/tonnage ratio for the train, then the ratio M/N is a constant k representing the number of average weight cars per locomotive unit at the desired HP/ton ratio. Hence, train length enters into this equation only indirectly as one of many variables affecting traffic volumes, locomotive utilization, and train speed. Although these secondary relationships may prove to be quite important, they can safely be ignored during the screening process; in which the following model can be used:

$$L = \frac{VD}{168\ U_\ell kS} \qquad \text{(A-1)}$$

Table A gives the number of locomotives required, as a function of traffic volume and distance, for a variety of values for k (cars/locomotive), U_ℓ (locomotive utilization), and S (train speed).

As an example of the way in which this formula might be used in a screening process, consider the power requirements for trains operating between two yards 300 miles apart at an average speed of 20 m.p.h., which an average utilization rate of 60 percent, and with one locomotive for every 25 cars. In this case,

$$L = \frac{VD}{168_\ell U\ kS} = \frac{300V}{168\ (.6)\ (25)\ (20)} = \frac{V}{168} \qquad \text{(A-2)}$$

TABLE A

IMPACT OF TRAIN SPEED AND POWER
UTILIZATION ON MOTIVE POWER REQUIREMENTS*

CASE 1:

LOCOMOTIVES:

S	1/S	U = .8	U = .4
10	.1	3.0 $VD(10^{-5})$	6 $VD(10^{-5})$
15	.067	2.0	4
20	.05	1.5	3
25	.04	1.2	2.4
30	.033	1.0	2
35	.029	.86	1.7
40	.025	.75	1.5
45	.022	.66	1.3
50	.02	.6	1.2

CASE 2:

LOCOMOTIVES:

S	1/U	S = 20	S = 40
.4	2.5	3 $VD(10^{-5})$	1.5 $VD(10^{-5})$
.45	2.22	2.66	1.33
.5	2.0	2.4	1.2
.55	1.82	2.19	1.09
.6	1.67	2.0	1.0
.65	1.54	1.85	.93
.7	1.43	1.72	.86
.75	1.33	1.60	.80
.8	1.25	1.5	.75
.85	1.18	1.42	.71

*locomotives required = $\frac{VD}{168\ U_{\ell} kS}$

where k = 25 and U and S are shown above.

Now assume that management has identified several opportunities for improving this service: 1) revise existing policies for assigning locomotives to trains, thereby increasing the utilization rate for this section to 75 percent; 2) upgrade the signalling system and the roadbed to allow an average speed of 30 m.p.h.; or 3) increase the HP/ton ratio, thereby increasing the average train speed to 25 m.p.h., but reducing the number of cars per locomotive to 20. The approximate effect of each option on locomotive requirements can readily be calculated using equation (A-1):

$$L_0 = \frac{300V}{168\ (.6)\ (25)\ (20)}$$

$$L_1 = (.6/.75)\ L_0 = .8L_0$$

$$L_2 = (20/30)\ L_0 = .67L_0$$

$$L_3 = (25/20)\ (20/25)\ L_0 = L_0$$

When used with the appropriate service and cost models, these initial estimates will indicate the most promising alternative and will suggest the precision of any additional analysis that might be required. If after the screening process no alternative seems worthwhile, management may decide to halt the analysis and to continue current procedures; if, on the other hand, all alternatives seem to have positive impacts, management may want a more detailed study as a basis for choosing the best means of upgrading this operation.

APPENDIX B

M.I.T. DEPARTMENT OF CIVIL ENGINEERING

Transportation Systems Division

Studies in Railroad Operations and Economics

Volume 1: Lang, A.S. and R.M. Reid, Railroad Car Movement Reliability: A Preliminary Study of Line Haul Operations, 1970.

Volume 2: Martland, C.D., Rail Trip Time Reliability: Evaluation of Performance Measures and Analysis of Trip Time Data, 1972.

Volume 3: Belovarac, K. and J.T. Kneafsey, Determinants of Line Haul Reliability, 1972.

Volume 4: Reid, O'Doherty, Sussman, and Lang, The Impact of Classification Yard Performance on Rail Trip Time Reliability, 1972.

Volume 5: Folk, J., Models for Investigating Rail Trip Time Reliability, 1972.

Volume 6: Folk, J., Some Analyses of Railroad Data, 1972.

Volume 7: Folk, J., A Brief Review of Various Network Models, 1972.

Volume 8: Lang, A.S. and C.D. Martland, Reliability in Railroad Operations: Executive Summary, 1972.

Volume 9: Sussman, Martland, and Lang, Reliability in Railroad Operations: Executive Summary, 1972.

Volume 10: Martland, C.D., Improving Railroad Reliability: A Case Study of the Southern Railway, 1974.

Volume 11: Sussman, J.M., C.D. Martland, Improving Railroad Reliability: A Case Study of the Southern Railway, Executive Summary, 1974.

Volume 12: Martland, C.D., Procedures for Improving Railroad Reliability, 1974.

Volume 13: Kneafsey, J.T., Costing in Railroad Operations, 1975.

Volume 14: Kerr, Sussman and Martland, Models for Investigating Train Connection Reliability at Rail Classification Yards, 1975.

Volume 15: Kullman, B.C., A Model of Rail/Truck Competition in the Intercity Freight Market, 1974.

Volume 16: Sloss, Humphrey and Krutter, An Analysis and Evaluation of Past Experience in Rationalizing Railroad Networks, 1975.

Volume 17: Humphrey, T.J., Framework for Predicting External Impacts of Railroad Abandonment, 1975.

REFERENCES

1. Area Handbook for Argentina, American University, Washington, D.C., 1969.

2. Argentina Railways, "Annual Report", Buenos Aires, 1968.

3. Brazilian Ministry of Transportation, "Transport Statistical Yearbook", Rio de Janeiro, 1971 and 1972.

4. Brazilian Federal Railways-RFFSA, "Statistical Yearbook", Rio de Janeiro, 1971, 1972, 1973 and 1974.

5. Brazilian National Department of Railroads-DNEF, "Railway Statistical Yearbook", Rio de Janeiro, 1971-1972.

6. Brazilian Federal Railways-RFFSA, "Railway System", Rio de Janeiro, 1974.

7. Brazilian Ministry of Transportation, "Brazilian Transport Survey", Rio de Janeiro, 1967.

8. Brazilian Federal Railways-RFFSA, "Annual Report", Rio de Janeiro, 1974.

9. Brazilian Federal Railways-RFFSA, "Annual Report for the Center Regional System", Rio de Janeiro, 1974.

10. Brazilian Federal Railways-RFFSA, "Legislation and Regulation", Rio de Janeiro, 1974.

11. Brazilian Institute of Statistics and Geography-IBGE, "Brazilian Statistical Yearbook", Rio de Janeiro, 1974.

12. Area Handbook for Brazil, American University, Washington, D.C., 1970.

13. Colombian Railways, "Railway Figures", Bogota, 1972 and 1973.

14. Colombian Ministry of Public Works and Netherlands Economic Institute, "Transport Study in the Area of the Magdalena River", Bogota, 1974.

15. Colombian Ministry of Public Works and Parsons, Brinckerhoff, Quode and Douglas, "Plan for Improvements in National Transportation", Bogota, 1961.

16. A Guide to the Mexican Markets, Marynka Olizar Publishers, Mexico, D.F., 1972.

17. J. Winberry, "Ferrocarril de Chihuahua al Pacifico: Mexico's Newest Railroad", Social Science Quarterly, 1975.

18. Banco de Mexico, S.A., "Mexican Statistics", Mexico, D.F., 1972.

19. Mexican Secretariat of Communications and Transportation-SCT, "National Railway Statistics", Mexico, D.F., 1968, 1969, 1970, 1971, 1972 and 1973.

20. Area Handbook for Mexico, American University, Washington, D.C., 1963.

21. Latin American Railway Association-ALAF, "Railway Statistical Yearbook", Buenos Aires, 1971 and 1973.

22. Organization of American States-OAS, "America en Cifras", Washington, D.C., 1974.

23. Pan American Railway Congress Association, "Bulletin", Buenos Aires, 1973.

24. C. Martland, "Methodologies for Developing and Evaluating More Effective Railroad Networks", Studies in Railroad Operation and Economics - Vol. 18, M.I.T., 1975.

25. Progress Report of the Methodologies for Developing and Evaluating Effective Rail Networks, M.I.T., October, 1974.

26. Jane's World Railways, McGraw-Hill Publications, New York, 1974.

27. Railway Directory and Yearbook, Temple Press, Ltd., London, 1975.

28. The Europa Yearbook, Europa Publications, Ltd., London, 1974.

29. Area Handbook for Colombia, American University, Washington, D.C., 1970.

30. "United Nations Statistical Yearbook", University of California at Los Angeles, Los Angeles, 1967, 1973 and 1974.

31. J.R. Meyer and M.R. Strazheim, Pricing and Project Evaluation, Brookings Institution, Transportation Research Program, Washington, D.C., 1971.

32. J. Sloss, T. Humphrey and F. Krutter, "An Analysis and Evaluation of Past Experience in Rationalizing Railroad Networks", Studies in Railroad Operation and Economics, Volume 16, M.I.T., 1975.

33. J.M. Sussman and C.D. Martland, "Improving Railroad Reliability: A Case STudy of the Southern Railway, Executive Summary", Studies in Railroad Operation and Economics, Volume 11, M.I.T., 1974.