AN ANALYSIS AND EVALUATION OF THE BRAZILIAN RAILWAY SYSTEM

by

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ABSTRACT

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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 transportation sector leading to a more efficient utilization of resources and the conservation of scarce petroleum. This program proposes large scale investment on track, terminals, and rolling stock, amounting to the unprecedented sum of four billion dollars. Past experience, however, has shown that the simple massive investment will not necessarily enhance the competitive position of a single transportation mode, and may result in an irreparable misallocation of resources. Furthermore, a number of other less capital-intensive alternatives are available. In fact, recent studies have proposed railroad rationalization as a potential solution to many of the current railroad problems, involving changes in fixed property, operations, policies, and equipment.

The purpose of this thesis is the identification and evaluation of such rationalization alternatives for the Brazilian railways. A systematic analysis of the country's network is undertaken to indicate the major problem areas. These include, among others, the non-uniformity of controlling organizations, the multiplicity of regulating agencies, the existence of different gauges, and the lack of a cost-based pricing system. A partial standardization of gauges is recommended for the strategic lines of the Southeastern network. A cost-benefit analysis is performed for the proposed network concluding that the benefits ensuing from a unified network in the productive heartland of the country amply justify the costs of implementation. Finally, the usefulness of screening models as an evaluation tool is demonstrated for several alternatives.

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CHAPTER I

INTRODUCTION

Since 1950, total intercity freight ton-kilometers in Brazil have increased more than five fold while rail ton-kilometers have barely tripled. During the same period, the rail market share in terms of ton-kilometers has declined from 24 percent to 16 percent while the market share of its major competitor — trucking — has increased from 50 to 74 percent. In 1973, the federal and state railroads in Brazil had their best financial performance of the last 20 years, running a deficit of more than US $160 million. These figures highlight the extensive impact of trucking on railroad operations over the past 20 years.[1]

[1]The railroads, as a system, always operated at a deficit although individual railroads might have reported profits. See [1].

Two major reasons can explain the disproportionate market share of truck transportation. First, the massive investment by the government, which owns the railroads and builds the highways, on the construction of highways, with the annual average investment on highways between 1970 and 1970 being almost ten times larger than the annual average investment on railroads. Secondly, the low level of service offered by the railroads diverted shippers to the other mode. The combination of these two factors generated a vicious circle with the government investing on highways because they seemed to offer a better service and the railroads deteriorating even more due to lack of funds needed to upgrade tracks, buy new equipment, improve operations, and thus provide better service.

This situation resulted in increased costs to society since a large share of the freight traffic could have been handled by a more efficient mode. In fact, railroads in general are conceded to be the most efficient mode for transporting heavy shipments over long distances inland. Although terminal costs are high, marginal line-haul costs are very low due to economies of scale on labor and power requirements.

Trucks, on the other hand, having much lower terminal costs, can move shipments over short distances more economically than railroads. However, they are not as well suited for long distance shipments due to higher line-haul costs.

With the impact of the energy crisis, the Brazilian government suddenly awakened to this situation. In fact, Brazil only produces 30 percent of its domestic oil consumption and thus began paying dearly for its heavy reliance on an oil-intensive mode. On the verge of a virtual collapse of its transport system, the government set out to reorganize the rail system and thus provide a more efficient option of transport for the shippers in general.

In October 1974, the Ministry of Transportation announced a four-year program for rail development to be implemented between 1975 and 1979.[2] This program involved a total investment of more than US $4 billion on the construction of new lines and terminals, on the upgrading of tracks and on the acquisition of new equipment. Although it is beyond the scope of this thesis to evaluate each of these investments we believe

[2] See [2].

that there are several other less capital-intensive alternatives capable of accomplishing the needed reorganization.

In fact, great care has to be taken to avoid the mistake of over-investment exemplified by the British experience. Indeed, after nationalization, British Rail sought to solve their chronic financial problems by building a multitude of pigeon-holed projects. It was encouraged in this by the government's new-found willingness to lend for investment, after years of capital rationing in a way similar to the present Brazilian situation. But much of what was built was either for traffic that no longer existed or for traffic that should be abandoned, summing up to one of Britain's most wasteful public programs.[3]

The above example clearly demonstrates that the simple massive investment on a single mode will not necessarily improve the competitive position of the mode. Furthermore, the future of the railroad is closely tied to the complex interactions between supply and demand for freight transportation deriving from

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[3]See [20].

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 transportation flows which are measured by statistics in terms of tonnage, modal split and origin-destination.

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, service reliability, probability of loss and damage and costs to the shipper. On the demand side, most important characteristics are those related to population, industries, agriculture, natural resources and economic conditions in general. The basic problem lies in the prediction of the equilibrium flow which results from the interaction between supply and demand.

Within this framework, four basic facts can be assumed in relation to the railroads. Firstly, the demand for rail transportation varies with the economic characteristics of the country. Therefore the railroads should be responsive to demand changes, increasing service or discontinuing service as might be required. Secondly, railroads can alter their equilibrium position by improving level of service. Such improvements should, ceteris paribus, divert to the railroad shipments being carried by other less efficient modes. Thirdly, the railroads, by improving the service provided, can bring about long-run activities shifts that increase the flow of commodities by rail. Fourthly, improving coordination of railroads with other modes would allow a more efficient use of the nation's transportation resources.

The four actions described above constitute what is more strictly defined as the rationalization process, i.e., any change in rail networks, operations, policies, or equipment that leads to a more efficient use of resources by railroads and shippers.[4] These changes do not necessarily imply in capital-intensive investment. On the contrary, several possible rationalization alternatives require more policy changes than capital expenditures. These include changes in

[4]See [25].

personnel costs and utilization changes in operating policies, changes in pricing policies and changes in service which would enhance the railroads' competitive position.

However, more capital investment possibilities such as changes in fixed property and equipment might be required and should be properly investigated, especially when important technological changes have occurred.

The primary goal of this thesis will be to undertake a systematic analysis of the Brazilian Railway system in such a manner as to apply the above-described concept of rationalization alternatives to a specific network and evaluate their impacts.

The structure of the present analysis will follow the methodological framework illustrated in Fig. I-1, which shows the supply and demand attributes of the systems as they interact to determine the overall performance of the railroad system.

Hence, within the framework suggested, we shall focus on the various factors where changes might achieve potential rationalization alternatives. These factors involve equipment, physical network,

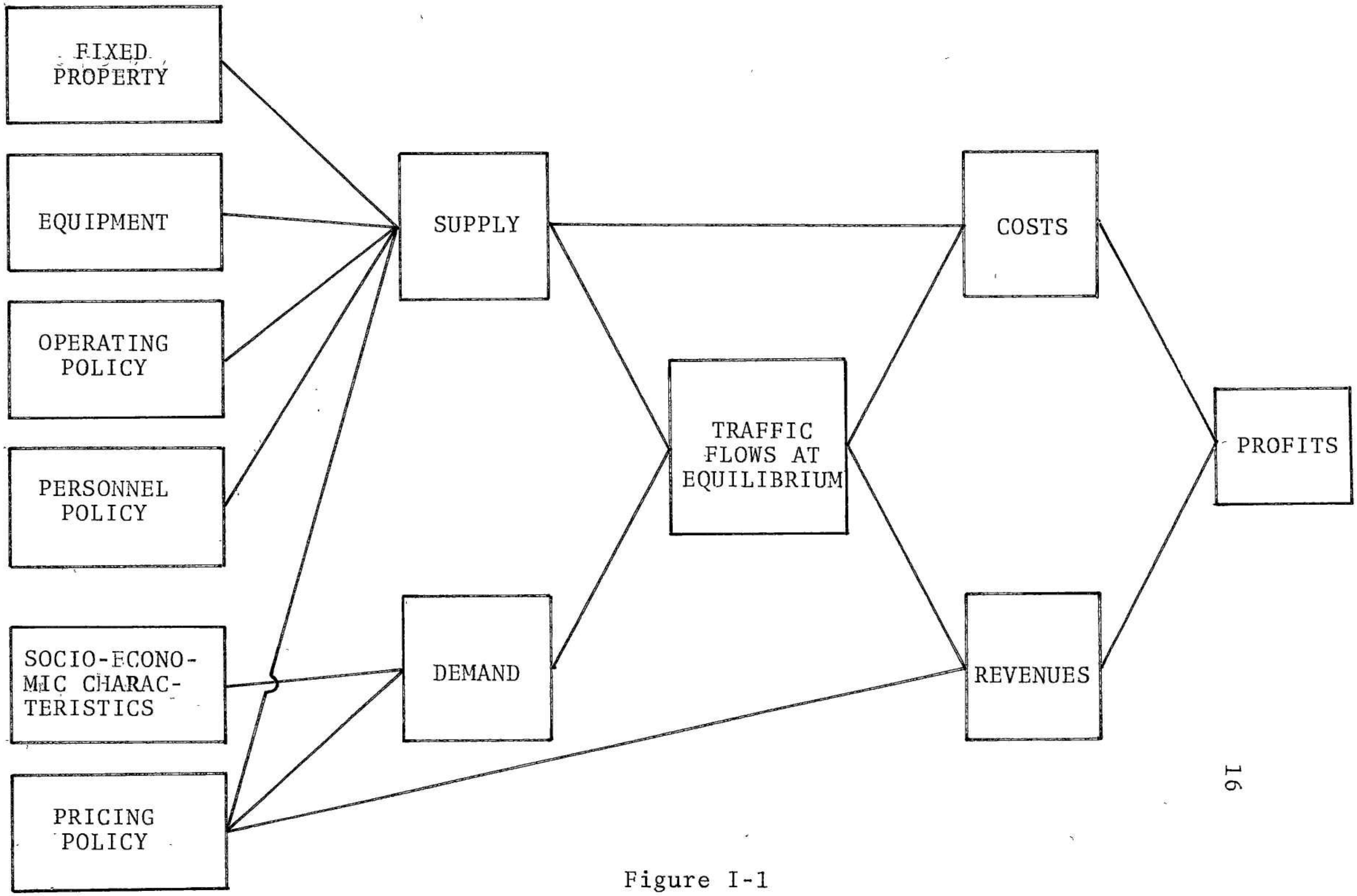

Figure I-1

Analysis Framework

operating policies, personnel policies and pricing policies, as well as specific problems for the Brazilian railroads such as institutional restraints and gauge break points.

Finally, we demonstrate the usefulness of screening models as a tool to evaluate these alternatives.[5] Of course, more sophisticated models could be used. Unfortunately, such models require extensive data and high computer costs, thereby making them impracticable to evaluate a large set of alternatives. Screening models provide at least a means to sort out the most promising solutions, and coupled with practical experience and judgment, can become powerful tools for use by railroad management.

[5] See [26].

CHAPTER II

INTRODUCTION TO THE BRAZILIAN RAILWAY SYSTEM

A. General Characteristics of the Country

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 Torrid Zone, Brazil enjoys relatively moderate climates, and even in the Amazon Basin, nights are relatively cool. Nowhere is the temperature regularly 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 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 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 and 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 have grown into great cities and the coastal lowlands and southern plains and plateau remain the most densely populated parts of the country with 70% of a total population of approximately 106 million people. The Central-West and the Northeast highlands have scanty populations and much of the great Amazon Basin remains uninhabited. There is a noted migration to the urban centers and presently only 50% of the people live in rural areas. However, a major shift in the settlement pattern — drawing the population inland — can be expected with the construction of the new capital, Brasilia, and the Trans-Amazon Highway.

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 restoration of 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. Liberation of price controls 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 the obstacles to exports, 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% and inflation had been reduced to 25-30%. Agricultural production and construction have been the leading sectors in generating 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% of total GNP, constituting about 80% of the total value of exports and employing more than 50% of the labor force.[1]

The main agricultural 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 soybean. Wheat is the most important agricultural import and comes mainly from the United States and Argentina.

(b) Industry

Industry in Brazil accounts for about 35% of GNP and employs about 15% of the labor force. Exports of manufactured goods, primarily to other Latin American countries, amounted to almost 20% of total exports.[2]

The industrial sector is concentrated in the triangular area formed by the cities of Sao Paulo, Rio de Janeiro, and Belo Horizonte. Their corresponding

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[1]See [23].
[2]Ibid.

states together produced 80% of the total manufacturing in the country. Other industrial centers include Recife, with food processing and Salvador with the Araxa Industrial Sector.

The major manufacturers are steel (with an output of around 10 million tons), chemicals, automobiles (now approaching one million vehicles per year), farm machinery, shipbuilding, electrical equipment, textiles, and cement. The production of rail 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% of domestic consumption.

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

(c) Domestic Trade

Domestic trade represents about 13% of GNP and employs about 12% of the labor force.[4]

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% of the area and 60% of the population, accounts for 80% of domestic income, whereas the states of the Central-West and Northeast, with 83% of the total area and 40% of the population, account for only 19%.

The wholesale organizations dealing in manufactured goods are, by and large, relatively small establishments, privately owned. Retail business varies a great deal and is generally carried on in cash.

(d) Foreign Trade

For the past years, the country's exports and imports have been expanding rapidly in response to the government's incentives, which are likely to

[4]Ibid.

continue for still some time.

The principal exports in 1970 were:

	US $ 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

Table II-1 [23]

The principal imports were

	US $ Million	% of Total
Machinery	1002	35.1
Raw Materials	488	17.1
Chemicals	446	15.7
Manufactured Goods	133	4.6

Table II-2 [15]

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

	Exports		Imports	
	$US*	%	$US*	%
United States	685	25	912	32
European Common Market	767	28	627	22
European Free Trade Assn.	356	13	342	12
Latin American Free Trade Assn.	301	11	313	11
Eastern Europe	137	5	57	2
Others	493	18	598	21
	2739	100	2849	100

Table II-3 [15]

*millions

(e) Transportation

For a long time, the Brazilian transport system has developed without the 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 in ton-kilometers between the various modes in 1973 is shown in Figure II-1.

The disproportionate share of truck transportation results both from the poor performance of the railroads, as well as from the massive investment on

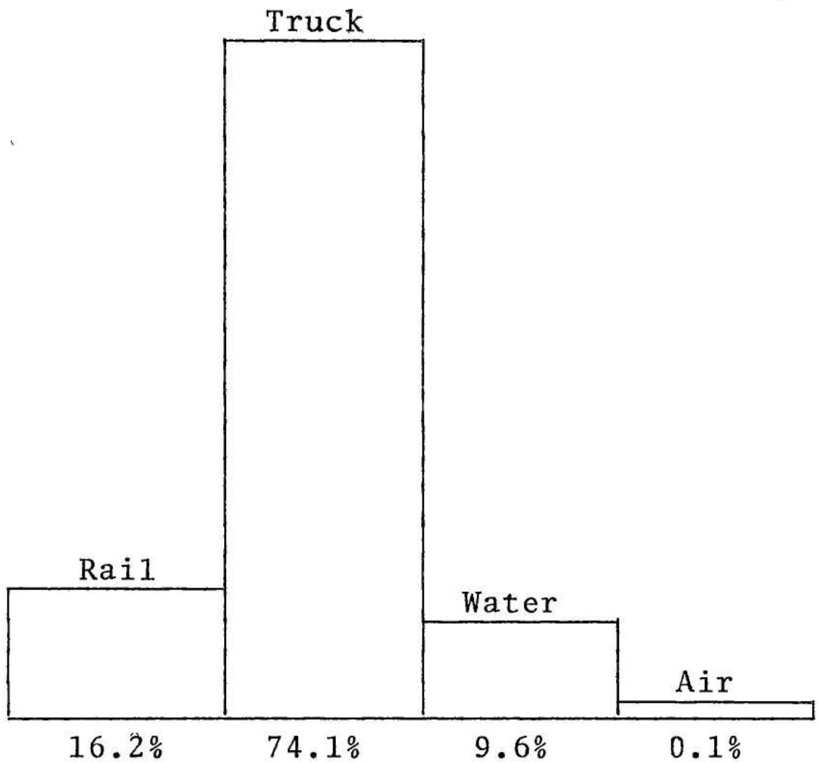

Figure II-1 [1]

highways.

Extensive highways have been built to open up new areas for development. These include the Belem-Brasilia, joining the North to the new capital, the Trans-Amazon highway, the Santorem-Cuiaba (under construction near the uppermost border of the country with the Guyanas and Venezuela), all integrating the Amazonic region and the Central-West.

In 1971, the Brazilian highway network had 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.

The railroads, which will be the subject of a more in-depth study, 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. For this reason the government is endeavoring to rehabilitate the railroads and will begin implementing the National Railway Development Program 1975-1979 for which considerable funds have been allocated.

By the end of 1970, the Brazilian merchant fleet had a total number of ships above 500, totalling 2.4 million tons of deadweight. The government, owner of over 80% of the ocean-going ships, controls the Lloyd Brasileiro which is the only cargo and passenger company engaged in international shipping. The government also owned at the time 41 tankers, which constituted the National Tanker Fleet.

The coastal shipping fleet consisted of 238 ships of which 30% were government owned and belonged to the National Coastal Navigation Company. Coastwise shipping has been increasing, due mostly to the increase of petroleum transport.

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% 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 airlines carry only 0.1% of total freight and 1.9% of inter-city passengers in the country.[5]

[5]See [1].

B. Development of the Railways

Early History

Planning for the development of railroads in Brazil originated in 1828 when the government authorized, by Letter of Law, the construction of railroads.[6] The government's interest was for political integration of the south and northeast as well as for economic development. There appears to have been insufficient benefits to attract investments until 1852 when construction of the first railroad was begun. The Maua Railroad from Rio to Petropolis was inaugurated in 1854.

The second railroad to be constructed in Brazil was the Recife - Sao Francisco Railroad, linking Recife with Vila do Cabo. This railroad was inaugurated in 1858 with 31 km of line.

The railroads originating in Rio de Janeiro continued their advance toward and beyond the coastal mountain chain and one, the D. Pedro II, backed by government funds, reached Sao Paulo in 1878 and Belo Horizonte in 1882.

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[6]See [29].

In the State of Sao Paulo, the Sao Paulo Railway Co. started operations in 1865 and the Paulista Railroad started in 1872.

In the south, the Rio Grande do Sul Railroad inaugurated in 1867 a 34 km line between Porto Alegre and Sao Leopoldo.

The following table[7] shows the increases in total route-kilometers from 1854 to 1954 and increases thereafter.

Year	Km
1854	14
1864	474
1874	1,283
1884	6,302
1894	12,260
1904	16,306
1914	26,062
1924	30,306
1934	33,106
1944	35,163
1954	37,191
1964	32,226
1974	29,418

Table II-4 [7]

[7] Includes only presently government-owned railroads.

It will be noted that between 1854 and 1874 only 1,700 km of line were constructed. To encourage construction at a more rapid rate than that achieved up to 1874, the government began paying a premium based upon kilometers of track constructed in a given period of time. As a result, more than 500 km of track per year were built during the next 20 years.

While the premium had a very stimulating effect on the kilometers of line constructed, it had a very detrimental effect on the characteristics of the railroads built, resulting in large numbers of heavy grades and sharp curves and the preponderance of 1.00 m gauge lines which are now contributing to existing high operating and maintenance costs.

Considerable difficulties were encountered in the construction of most lines. Many if not all of the problems were due to inadequate planning and financing, and as a result, the period between initial construction and inauguration of service extended over many years.

Some of the lines were built by private companies, which were later taken over by the government. As the network increased, numerous consolidations were made, particularly when connections were completed between individual railroads.

Many railroads were built for the express purpose of moving specific commodities from production areas to the coast for export and transporting imported manufactured goods on the return movement. During the period of this great expansion of lines, the principal commodities transported were agricultural, such as coffee, sugar, cotton, grain, and cocoa.

The steady transfer of production to the south and west because of soil depletion, the reversion of previously productive areas to pasture, dairy, or poultry products, and the increasing absorption of products within adjacent cities where industry was being developed were all factors detrimental to the railroads and favorable to the development of highway transport. These changes in production and distribution patterns contributed to substantial losses of traffic for all of the railroads.

The Development of a Federal System — RFFSA

As the control of the railroads was taken over by the central government and new lines were built, the administration of the railroads was placed under various governmental agencies.

By 1957, however, it became apparent to the federal government that there was a need to coordinate further all federal railroads under a common administration to effect better control and to permit flexibility of action.

The RFFSA — Federal Railway Network — was then created, incorporating the railroads owned and administered by the federal government.

The RFFSA is, in effect, a corporation in which the federal government holds 87.2% of the common stock, the states own 10.2% of preferential stock, and municipalities own 2.6% of preferential stock.[8]

The principal reason for consolidating the railroads owned by the government was to free them from the bureaucratic methods and obstacles which, up to that time, had not permitted the use of flexible business methods capable of solving their problems. In practice, however, this body is by no means divorced from the government and retains most of the former methods.

The RFFSA is divided into four regional systems and fourteen divisions which correspond approximately to the former separate railroads. They are shown in

Table II-5.

The federal railroads were built with three different track gauges — 0.76 m, 1.00 m, and 1.60 m. Subsequent to the original constructions there has been limited widening of gauge; however, all three remain in use, constituting a problem that will be extensively discussed in following sections. The route-kilometrage of the network, as of 1973, classified by gauge, is shown in Table II-6a.

Since the formation of the RFFSA there has been a 4.2% decrease in total network route-kilometrage, especially for the 0.76 m gauge lines (- 72%) and 1.00 m gauge lines (- 16%) as opposed to a 3% decrease for the 1.60 m gauge lines.[9]

A total of 1,053 km are electrified on 3000 V (dc), mainly on 1.60 m gauge lines.[10]

The State Railroads of Sao Paulo — FEPASA

The State Railroads of Sao Paulo developed similarly to those of the Federal System with all originating as private companies, principally for the

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[8] See [10].
[9] See [7].
[10] Ibid.

RFFSA Divisions	Former Railroads
Northeast	
1º Division	Sao Luiz - Terezina Railroad
2º Division	Cearense Network
3º Division	Nordeste Railway Network
4º Division	Leste Brasileiro Railway
Center	
5º Division	Centro-Oeste Railway
6º Division	Central do Brasil Railroad
7º Division	Leopoldina Railroad
8º Division	Suburbs (Rio)
Center-South	
9º Division	Santos - Jundiai Railroad
10º Division	Noroeste do Brasil Railroad
South	
11º Division	Parana - Santa Catarina Railway
12º Division	Dona Teresa Cristina Railroad
13º Division	Rio Grande do Sul Railway
14º Division	Santa Catarina Railroad

Table II-5 [1]

Track Gauge	Route Kilometers
0.76 m	202
1.00 m	22,196
1.60 m	1,666
Total	24,064

Table II-6 [2]

movement of agricultural products for export or to the large cities for processing.

Each of the railroads required financial assistance from the state during numerous periods and eventually the assistance became so substantial that the state assumed either complete or partial ownership sufficient for control.

In 1971, all the railroads owned and operated by the state were grouped under a single system called FEPASA — Sao Paulo Railway Co.

The FEPASA is a stock company which operates in a manner similar to the RFFSA. It is divided into three operational systems:

(1) The Mogiana system, comprising the former Mogiana and Sao Paulo - Minas railroads

(2) The Paulista system, constituted by the former Paulista and Arazoquara railroads

(3) The Sorocabana system, formed by the former Sorocabana Railroad.

The Sao Paulo railroads are of two gauges — 1.00 m and 1.60 m — with the following route kilometrage:

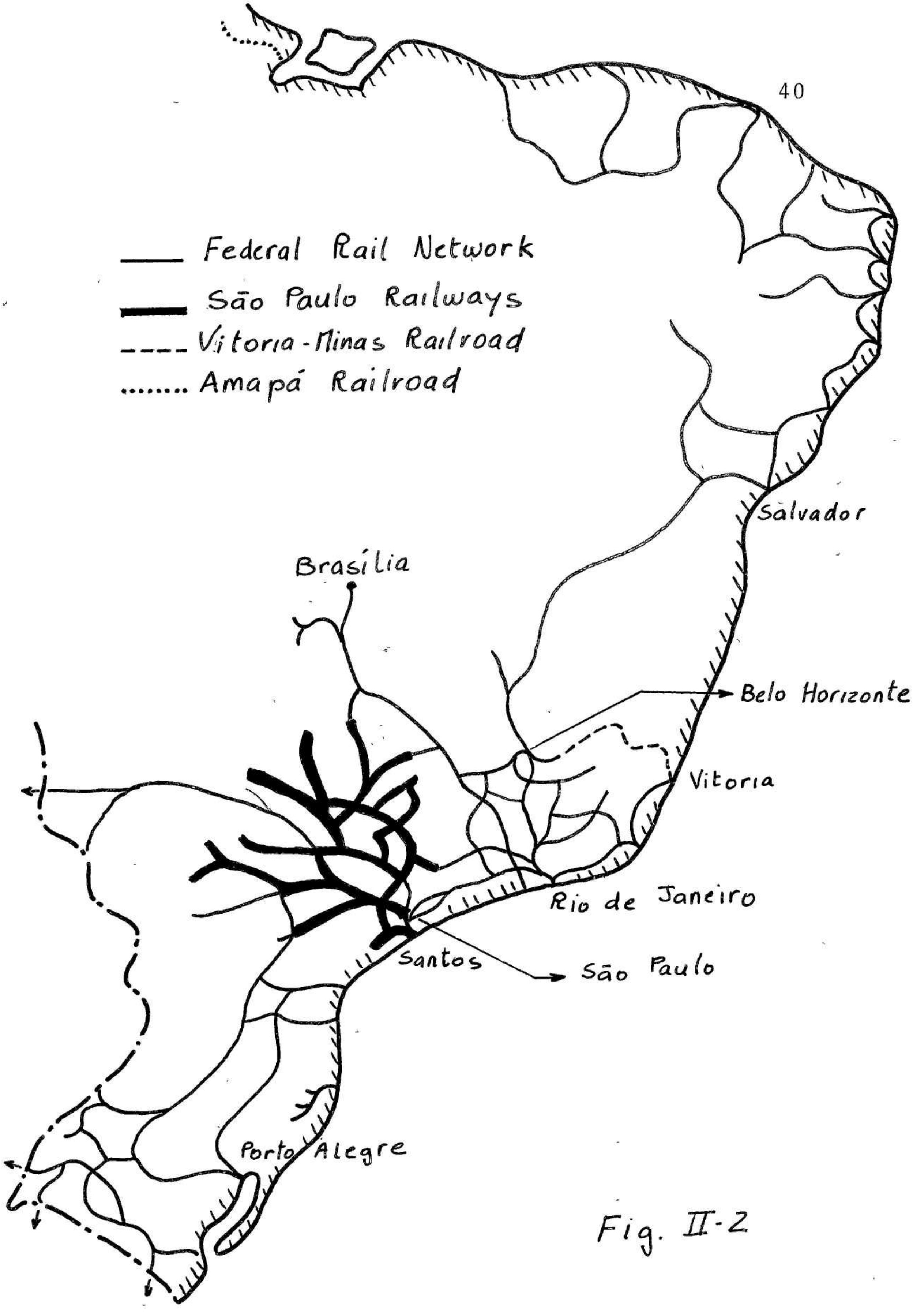
Track Gauge	Route Kilometers
1.00 m	3,660
1.60 m	1,647
Total	5,307

Table II-6a [5]

The 3000 V (dc) system is used on the 1,196 km of electrified, broad gauge lines.[11]

The Brazilian Railway System is shown in Figure II-2, including the two private railroads — Vitoria - Minas and Amapa.

[11] See [15].



Federal Rail Network
São Paulo Railways
Vitoria-Minas Railroad
Amapá Railroad
Salvador
Brasília
Belo Horizonte
Vitoria
Rio de Janeiro
Santos
São Paulo
Porto Alegre

Fig. II-2

C. Transportation and Railway Organization

Within the federal government there are several departments and agencies which have, in varying degrees, authority over and responsibility for various facets of the Federal Railway Network (RFFSA).

Each of these is described below. It is obvious that the legislation under which these were established has caused conflicts which interfere with the proper operation of the railroads. The authority for establishing policies was divided and the responsibility for successful operation not charged to the agency having the authority to change conditions. As will be discussed later, the RFFSA has little voice in the policies adopted in a number of areas, even though the policies may have a great effect on the operation of the railroads, particularly from a financial standpoint.

Ministry of Transportation (MT)

The MT is the ultimate authority over national transport in the following sections:

General Coordination of Transportation
Railway Transportation
Highway Transportation
Maritime, Coastal and River Navigation
Ports and Shipping Construction.

In relation to the RFFSA, the control of the MT is only indirect but not less effective. In fact, although the RFFSA was established as an autonomous enterprise, with an issuance of capital stock similar to that of a private company over which the authority of the MT was defined as being restricted,[12] for all practical purposes it is completely subordinated to the Ministry of Transportation.

Brazilian Transportation Planning Enterprise — GEIPOT

In 1965, recognizing the need for a more effective coordination of transportation planning efforts, the government created the GEIPOT. This agency has been responsible for promoting studies leading to the establishment of a multimodal, integrated transportation planning policy for the country. Today, as an autonomous enterprise, it can perform transportation studies for any federal, state, or local agency. Although it has no control over the railroads, it can affect them through its advisory capacity, reporting directly to the Minister of Transportation.

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[12] See [9].

National Department of Railways — DNEF

The DNEF was established in 1941 to supervise the development and operation of the railroads which were then under several types of management, including those under private ownership or operation and those under state and federal operation.[13]

The DNEF continued to exercise this authority over the various railroads until 1957 when the RFFSA was established to operate the federal railroads.[14]

As an entity subordinated to the Minister of Transportation, the DNEF has now the responsibility of directing, guiding, controlling, and supervising the policies of rail transportation including carrying out of studies and plans for the improvement and construction of railroad lines.

In practice, however, to avoid complete confusion, since many of these attributes are also given to the RFFSA, the DNEF restricts itself to the planning and supervision of the construction of new lines and works, financed by funds made available to it by the

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[13] See [29].
[14] Ibid.

federal government, which result from arbitrary percentages applied to the federal income and railways' freight revenue and bear no relationship to the money required for needed railroad investments.

In such a case, it is reasonable to expect that all the money will be spent so as to avoid any reduction in future funds and that the expenditures will be made for those projects having the greatest public appeal rather than on less dramatic projects such as changes of gauge, new classification yards, or rail replacement.

The Sao Paulo Railroads

The government of the State of Sao Paulo has 13 secretariats of which one is the Secretariat of Transportation, which functions, in relation to the Sao Paulo Railway Co. — FEPASA —, in a similar way as the Ministry of Transportation does in relation to the RFFSA.

Conclusion

The mere description of the powers and responsibilities of the various governmental organizations which in one respect or another affect the oprations and financial results of the railroads, should make it amply clear that the wide dispersion of responsibility as now prevails is one of the major causes of the present unsatisfactory state of Brazil's railroads. It is not sufficient that most of these bodies are ultimately responsible to the Ministry of Transportation. Most of the functions of these organizations should be integral responsibilities of the railway management itself, as they are so closely related to the efficient and financially successful operation of the railroads. The proliferation of responsibilities and authority among a number of independent agencies is contrary to the fundamental concept of good management, that authority and responsibility must be in the same hands. We believe that until this basic fault is corrected, an effective railway organization is not possible.

Furthermore, the existence of a separate state organization in Sao Paulo, responsible not to the federal government but to the state administration, adds one further factor complicating the relationship between railroad organizations and the government, ruling out the possibility of a truly effective national railway system.

D. Financial Results

Federal Railway System

(1) Revenues

In 1973, the total revenues of the Federal Railway Network were $1,356,492,000 (200 million dollars in U.S. currency).[15] The following table shows the relative importance of each region of the system, with the Center system contributing 47.0% of the total, the Southern system 22.3%, the Center-South system 21.1%, and the Northeastern 8.7%.

Regional System	Revenue (000)
Northeast	118,521
Center	637,353
Center-South	285,878
South	303,231
Total RFFSA	1,356,492[16]

Table II-7 [2]

The sources of revenue for that same year are shown in Table II-8 as a percentage of the total revenue.

[15] See [7].
[16] Includes revenues from the Central Administration, which cannot be attributed to any individual region.

Source	Percent
Freight	64.92
Passenger	13.28
Complementary	0.08
Incidental	21.82
Total	100.00

Table II-8 [2]

The percentage of the total represented by revenues from passenger service is relatively high by American standards, and is due to the lack of personal automobiles, to the commuter services offered by many lines serving the larger cities, and to the low fares charged.

Complementary revenues include rentals of equipment, pickup and delivery service, commissions from third parties, and warehouse income.

Incidental revenues include those from telephone and telegraph services, concessions, sale of scrap, rentals of buildings and the supply of water and electricity to others.

(2) Expenses

The table below shows the expenses and the deficits for each regional system.

The total expenses in 1973 were Cr $2,133,493,000 compared to total revenues of Cr $1,356,492,000, resulting in a deficit of Cr $777,001,000.[17]

The table shows that all but one system contributed to the total deficit, the largest amount by the Central Regional System with Cr $452,237,000, representing 58.2% of the total. In fact only two divisions — 9º and 12º — out of 14 were profitable.

Regional System	Expenses (000)	Profit or Deficit (000)
Northeastern	322,967	-204,446
Central	1,089,590	-452,237
Center-South	282,558	+ 3,320
South	357,745	- 54,514
Total	2,133,493	-777,001

Table II-9 [2]

[17] See [7].

However, the measure of success of the operation of a railroad is not by its total deficit or profit, but by its operating ratio, that is, the ratio of the expenses to revenues. Table II-10 shows the operating ratios for the four systems.

Only 6 divisions reported operating ratios lower than the average for the RFFSA, i.e., 1.57. The best performance was by the 12º Division with 0.60 and the worst by the 1º Division with 3.70, which indicates that for every cruzeiro received almost four were spent.[18]

Regional System	Operating Ratio
Northeast	2.72
Center	1.71
Center-South	0.99
South	1.18
Total	1.57

Table II-10 [2]

[18] These figures seem to indicate that the railroad profitability follows the actual variations in economic development between the several regions [see Section A].

The expenses include some provision for depreciation. However, the practice has been to do this on an arbitrary basis that bears no relation to cost and life expectancy of the depreciable assets. Had proper charges been made to operations for depreciation, the total expenses would have been greater.

The figures over time, however, indicate that the operating ratio has been improving. For data from 1966 to 1973[19] a time series fit was performed showing the following:

Year	Actual Operating Ratio	Estimated Operating Ratio	Actual ÷ Estimated
1967	2.20	1.89	1.16
1968	1.61	1.83	0.88
1969	1.64	1.77	0.93
1970	1.58	1.70	0.93
1971	1.66	1.64	1.01
1972	1.66	1.58	1.05
1973	1.66	1.51	1.04

Table II-11

[19] See [1] and [7].

The fitted equation was

$$Y = 1.956 - 0.063X$$

where Y = operating ratio

X = one year unit with the origin in 1966.

It is interesting to note with the due caution that if this trend were to continue at the same rate the RFFSA would be breaking even 15 years from 1966, that is, in 1981.

The total expenses include those of four general categories, as follows:

(1) Maintenance of Way and Structures — includes the expenses of maintaining all trackage and buildings of the railroad.

(2) Maintenance of Transport Equipment — includes the total cost of maintaining locomotives, freight, and passenger cars.

(3) Traffic expenses are those of operating all trains, including fuel, water, and supplies for locomotives as well as labor.

(4) General expenses include those of management, accounting, and legal departments, claims for loss and damage, social benefits of employees,

and others.

In Table II-12 these expenses are given for 1974 with the percentage each one represents.

The magnitude of the problem of putting the entire system on a break-even basis is illustrated by the several alternatives which can be selected between the two extremes of

(1) increasing revenues by 60 percent while maintaining present expenses, or

(2) decreasing expenses by 36 percent while maintaining present revenues.

Department	Expense (000)	%
Maintenance of Way	628,492	21.6
Maintenance of Equipment[20]	612,230	21.1
Traffic	1,216,862	42.1
General	441,736	15.2
Total	2,899,326	100.0

Table II-12 [10]

[20] Includes depreciation.

Sao Paulo Railways

The Sao Paulo railroads have also been running an unprofitable operation. In 1973 its revenues amounted to Cr $365,234,000 (52 million dollars in U.S. currency).[21] The sources of revenue are shown below:

Source	Percent
Freight	73.0
Passenger	21.9
Complementary	4.0
Incidental	1.1

Table II-13 [15]

In the same year expenses reached Cr $575,703,000 (83 million dollars in U.S. currency), creating a deficit of Cr $210,469,000 (31 million dollars in U.S. currency).[22] The percentage of each department's expense in 1973 to the total is shown in the table below.

[21] See [15].
[22] Ibid.

Department	Cr $ 1000	%
Maintenance of Way	102,337	17.8
Maintenance of Equipment	145,320	25.2
Traffic*	228,612	39.7
General	99,434	17.3
Total	575,703	100.0

Table II-14 [5]

*includes road transportation

The figures for the operating ratio trend of the Sao Paulo railroads are shown in Table II-15[23] with the estimated values obtained from the following time series fit:

$$Y = 2.010 - 0.065X$$

where Y = operating ratio

X = one year unit with the origin in 1966.

Following the same trend, it would take the Sao Paulo railroads 16 years, from 1966 to 1982, to start breaking even.

[23] See [15] and [16].

Year	Actual Operating Ratio	Estimated Operating Ratio	Actual ÷ Estimated
1967	2.00	1.95	1.03
1968	1.86	1.88	0.99
1969	1.81	1.82	0.99
1970	1.66	1.75	0.95
1971	1.72	1.69	1.02
1972	1.63	1.62	1.01
1973	1.58	1.56	1.01

Table II-15

E. Traffic Characteristics

The purpose of this section is to describe the traffic characteristics of both freight and passenger travel. The operating performance of the railroads, in terms of operating efficiency and equipment utilization, is more thoroughly analyzed elsewhere.

Freight Traffic

In 1973, the federal railroads carried 35.5 million net tons of freight with an average length of haul of 399 km, which signifies 14.1 billion net ton-km of freight. The Sao Paulo railroads carried 10.0 million net tons for a total of 3.5 billion net ton-km and an average haul of 346 km.[24]

To make a more complete analysis of the movement of freight traffic, particularly for the establishment of rates and divisions of revenues, it is essential to know the character of the movement. The character of the movement of freight is normally considered on these bases:

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[23] See [7] and [15].

(1) Loadings by proportion of full carload (FCL) and less-than-carload (LCL) shipments

(2) Movement from origin to destination by proportions of local, interchanged, and overhead traffic

(3) Average length of haul by commodity.

However, there was no information available concerning such measures. The only data were volumes of the major commodities carried by the federal railroads which are iron ore, petroleum products, and cement. An interesting comparison between the indices (where 1969 = 100) of production of iron ore and its transport by the federal railroads (Table II-16) shows clearly that they were not able to accommodate the increase in demand, losing thereby an important share of the traffic to truck transportation.

Year	Transport	Production
1969	100	100
1970	106	110
1971	95	114
1972	85	141
1973	114	149

Table II-16 [4,1]

The three major commodities carried by the Sao Paulo railroads are sugar, fertilizers, and cement. However, there is no time series data available on tonnage of individual commodities to study the responsiveness of the railroad to variations in demand.

Passenger Traffic

The total number of passengers using train service and the passenger-kilometers travelled on interior trains are summarized in the following table for the two systems:

System	Number of passengers (1000)			Interior Pass-Km (10^6)	
	Interior	Commuter	Total	Total	Per Passenger
Federal	25,407	233,842	259,249	2466	97
Sao Paulo	13,763	32,422	46,185	1928	140

Table II-17 [5]

The trends for both the federal and the Sao Paulo networks indicate that passenger traffic is declining, with the number of passengers and passenger-kilometers decreasing every year. However, the average length of trip is increasing.[25] Although we have not studied the bus transport industry, this seems to indicate that buses are being used increasingly for the shorter trips on which, with the improvements in the highways, better service and lower rates are offered. The market share trends in passenger-km of the several modes are shown in Figure II-3.

[25] Ibid.

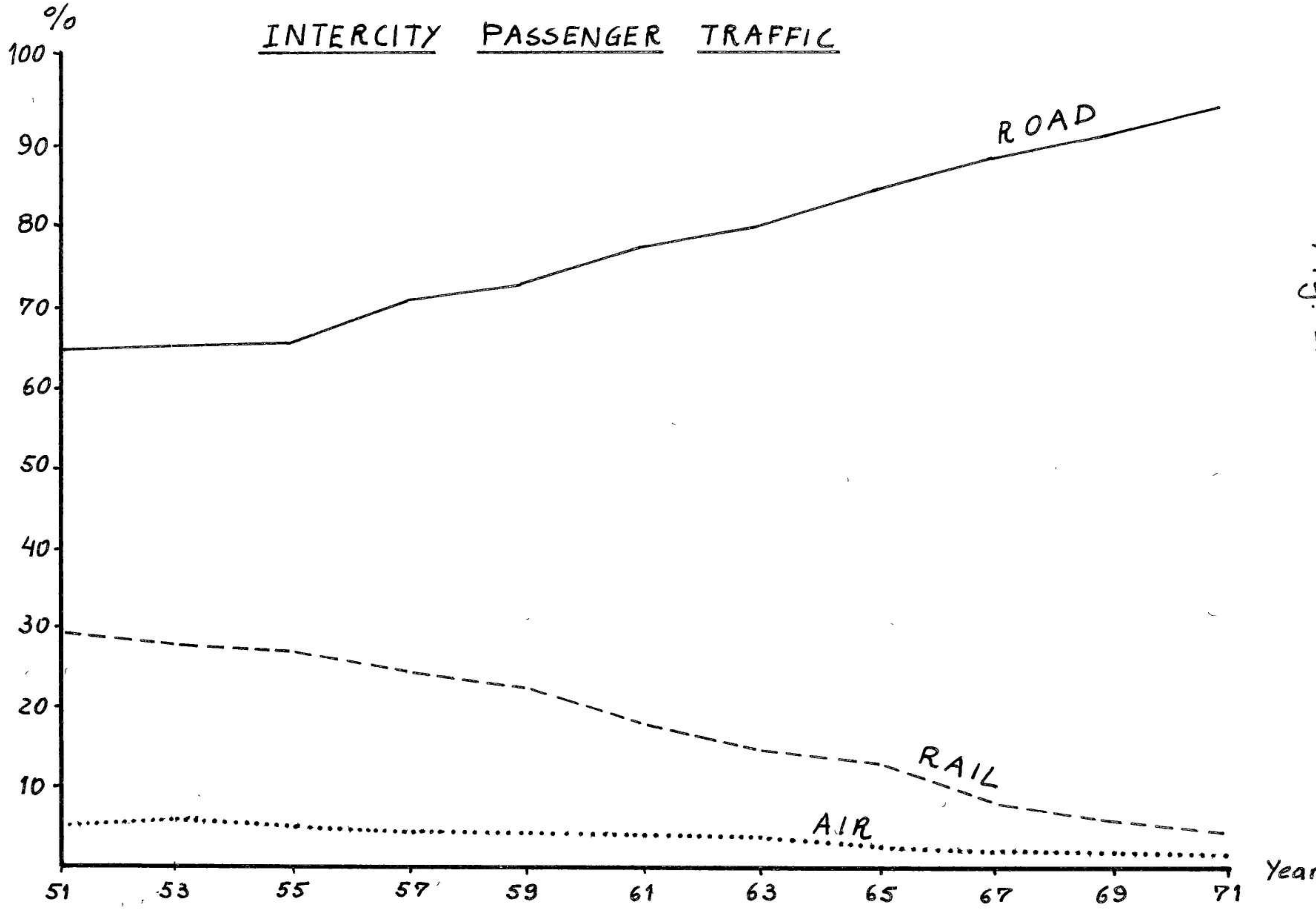
INTERCITY PASSENGER TRAFFIC
%
100
90
80
70
60
50
40
30
20
10
ROAD
RAIL
AIR
Year
51
53
55
57
59
61
63
65
67
69
71

Fig. II-3

F. The Gauge Problem

An examination of the Brazilian national system will show clearly the various aspects of a situation that can be defined as the "gauge problem":

(1) Almost 90% of the railroad lines are of the narrow 1.00 m gauge, whereas 10% are of the wide 1.60 m gauge. Differeng gauges appear in short isolated lines, such as the standard 1.435 m gauge (for 147 km) and the old 0.76 m gauge (for 202 km).

(2) Although the 1.60 m gauge lines represent only 10% of the total network, one third of the total freight and 80% of suburban passengers are carried over such lines.

(3) The wide (1.60 m) gauge network is virtually surrounded by narrow (1.00 m) gauge lines, forcing the transfer of freight and thus increasing the cost of transportation and the probability of loss or damage due to additional handling, and decreasing reliability and overall quality of service.

(4) This problem is not restricted to domestic traffic alone. In effect, the narrow (1.00 m)

gauge network in the Southern region is not connected with similar networks in Argentina and Uruguay which, on the border with Brazil, have standard gauge networks.[26]

Many questions arise from this type of situation for which there are several different solutions. Standardization of gauges is only one of them: the only one that completely eliminates the problem, but also the most expensive. In the following section, an attempt will be made to understand the particular characteristics of the Brazilian situation as to why it constitutes a problem, what is the best alternative to solve it, and how it should be implemented.

Historical Background

The reasons for the present existence of several gauges are common to most countries which started their railroad development during the last century, when each railroad was an end in itself and the idea of an integrated network was not yet conceived. However, several countries were able to overcome the problem of the diversity of gauges.[27]

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[26] See [30] for the detailed maps.
[27] Still in the beginning of railroad history, the

In Brazil, the first gauge conversion occurred in 1883 when the Petropolis Imperial Railroad changed its gauge from 0.76 m to 1.00 m for a total distance of 18 km.

In 1916, the Paulista Railroad (of the Sao Paulo Railways) started a large program to widen its gauge from the narrow 1.00 m gauge to the 1.60 m gauge. This, in turn, caused the Araraquara Railroad to take the same step in order to keep a good interchange of freight between the two railroads, and as a consequence, 431 km of route were converted to the wide gauge.[28]

Another railroad, the Centro-Oeste Railroad, now part of the RFFSA system, while upgrading its tracks on a distance of 173 km, changed its gauge from 0.76 m to the 1.00 m gauge.[29]

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first standardization program was carried out in England as a result of the Gauge Regulation Act of 1846. Later, in 1885, the United States put into effect the largest gauge unification program by changing 18,000 km of railroad lines to the standard 1.435 m gauge. Also Russia changed its gauge from 1.829 m to 1.524 m. More recently, Australia and India also carried out important standardization programs, without, however, achieving a single gauge network such as those countries which completed their programs at earlier dates had. See [29].

[28] Ibid.

[29] Ibid.

This briefly summarizes what has taken place in Brazil in terms of gauge standardization. As we can see, all the lines which had their gauges changed (approximately 600 km) represent a small part of the total network which reached 37,191 km in 1954.[30]

The three different motivations for changing gauges were:

(1) Independent decision by a railroad to change gauges for its own convenience (Petropolis Imperial Railroad and Paulista Railroad)

(2) Conversion forced upon a railroad for a better handling of interchanged traffic from a larger railroad (Araraquara Railroad)

(3) Conversion following the upgrading of tracks (Centro-Oeste Railroad).

In addition to individual actions taken by the railroads such as noted above, extensive debates have dealt with the gauge problem. In 1946 a major proposal was put forth by the Brazilian-American Mixed Commission that the construction of new lines be made within the specifications of the 1.60 m gauge even if the actual gauge used was to be the 1.00 m gauge.

[30] See [3].

Since then, all new construction has followed that recommendation and today there is approximately 4,300 km, representing almost 15% of the total, which could be converted from narrow to broad gauge with a minimum disturbance of the substructure.[31]

In terms of railroad planning, however, besides this tendency to build new lines with 1.60 m substructure, no major study on gauge standardization has been undertaken and the problem still persists.

The Present Situation

The Brazilian railroad network can be roughly divided into 3 sectors. In two of these sectors, only one gauge exists, the 1.00 m gauge (see map in Figure II-4).

The first such sector comprises the northern part of the network, including the 1º, 3º, 4º and most of the 14º Divisions of the RFFSA, amounting to 8,422 km.

The other sector where there is only the 1.00 m gauge lies to the south of Sao Paulo and is composed

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[31] See [6].

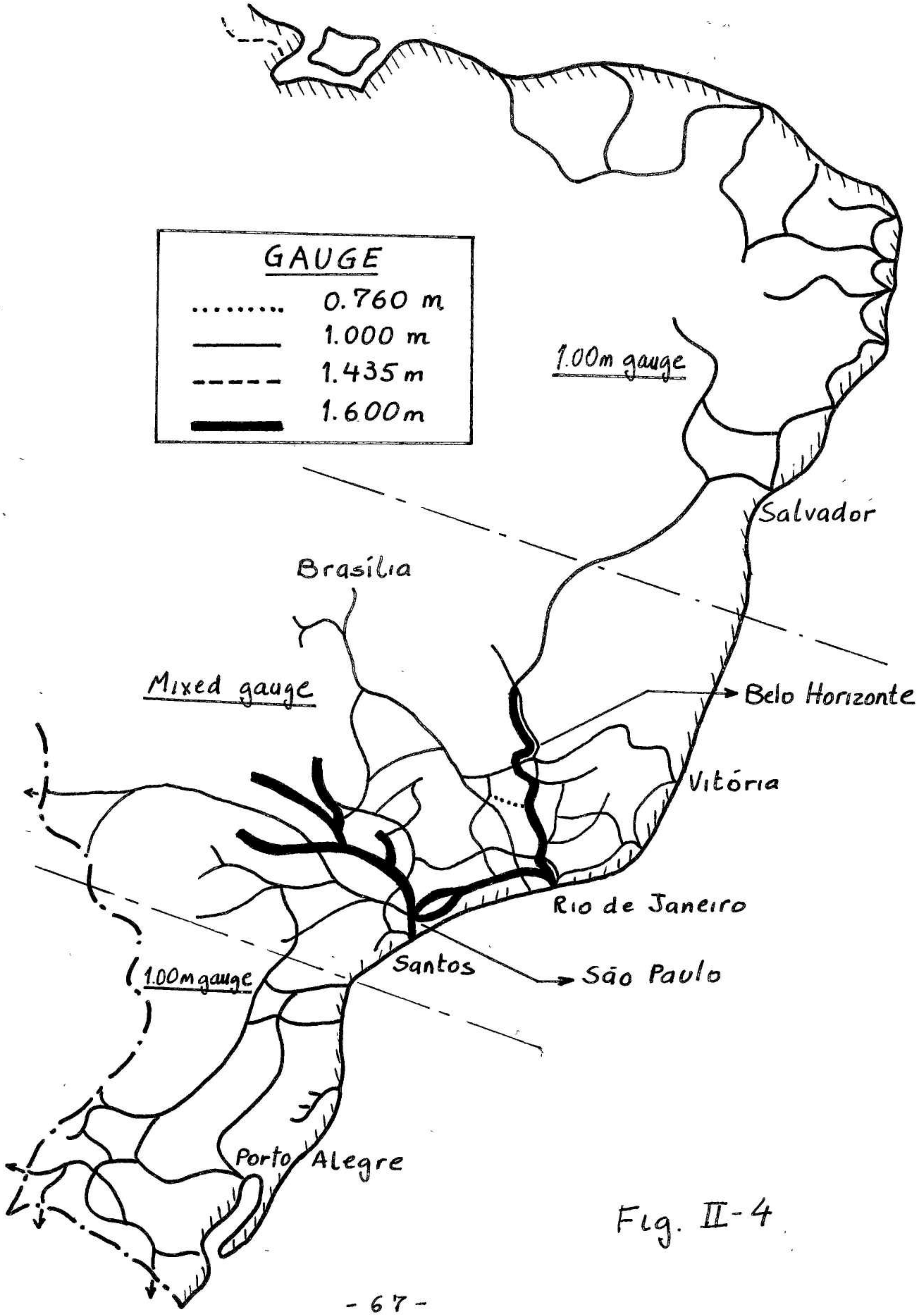
GAUGE
0.760 m
1.000 m
1.435 m
1.600 m
1.00m gauge
Salvador
Brasília
Mixed gauge
Belo Horizonte
Vitória
Rio de Janeiro
Santos
São Paulo
1.00m gauge
Porto Alegre

Fig. II-4

of the 11º, 12º, and 13º Divisions of the RFFSA and a small part of the FEPASA. This sector is 6,870 km long.

The third sector, located in the southeast part of the country, where more than 80% of the industry is located and which generates the largest and most important volumes of railroad freight, is precisely where the gauge problem lies. This sector contains most of the FEPASA, the Vitoria - Minas Railroad, and the 5º, 6º, 7º, 8º, 9º, 10º and part of the 14º Divisions of the RFFSA, totalling 15,483 route-km with 202 km of 0.760 m gauge, 13,615 km of 1.00 m gauge, and 1,666 km of 1.60 m gauge.

The alternatives used to overcome the diversity of gauges in Brazil have been of three kinds:

(1) Freight transfers

(2) Change of trucks

(3) Mixed gauges.

A more detailed report on the characteristics and performance levels of these is given below.

(1) Freight Transfers

A description of the major yards for transferring freight between different gauge lines follows.[32] See Figure II-5 for the exact location.

(a) Barra Funda - Sao Paulo.

In 1973, this yard handled 256,571 tons of transfer freight equivalent to more than 11,400 freight cars. The average holding time was 6 days, although the operation is thoroughly mechanized.

This yard provides a good example as to how the gauge problem can draw shippers away from the railroad. The paper industry located nearby had been using the railroad regularly for transporting its inputs and outputs. As the demand for paper grew on the market over the last years, the inventories began to drop, making the speed of delivery a crucial factor for the paper industry, as it must meet the competition from imports attracted by the higher prices. Since the transfer operation for its products at Barra Funda yard required anywhere from 7 to 15 days and increased damages due to handling, the paper industry was forced

[32] See [6] for a more detailed description.

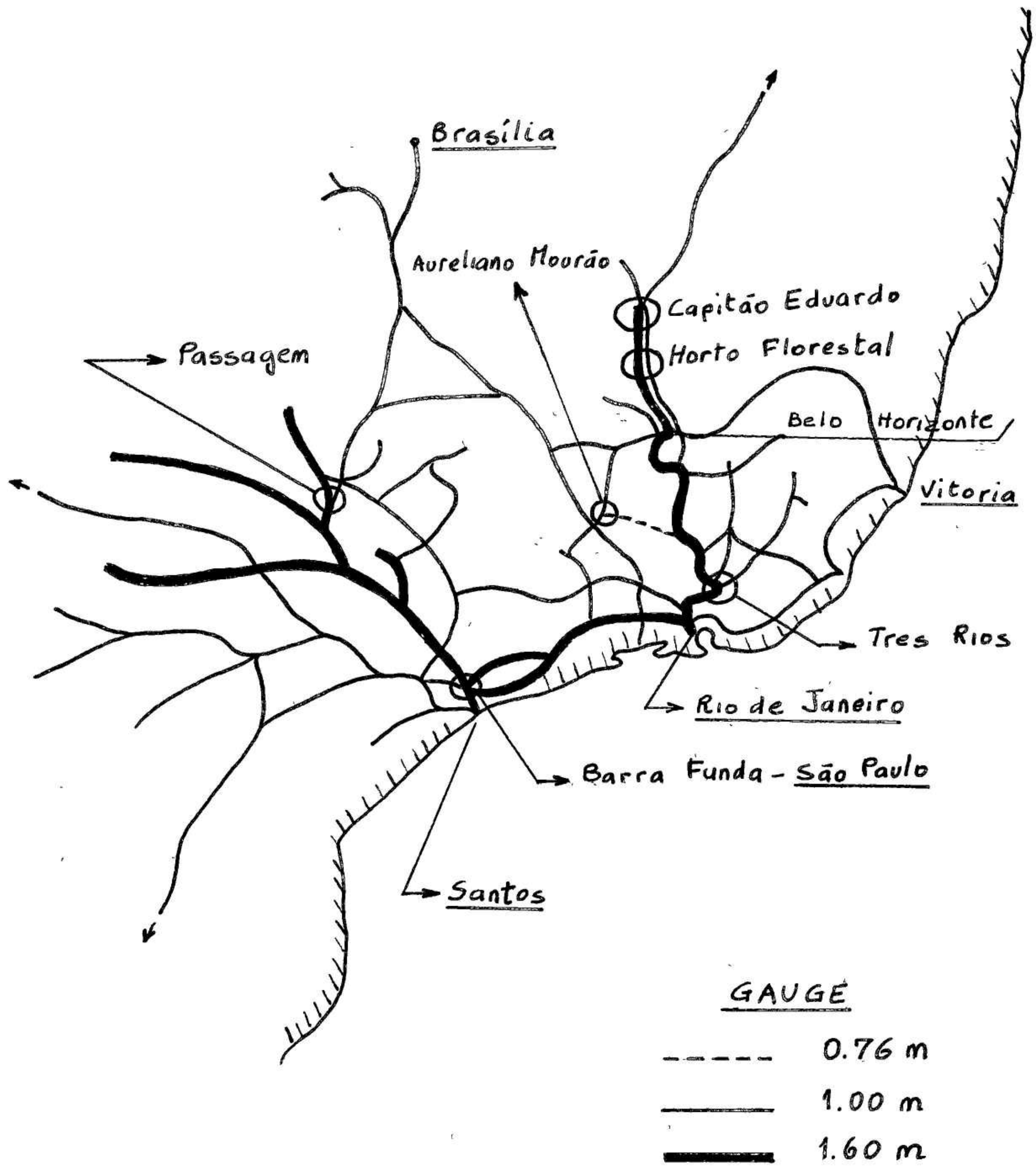
Brasília
Aureliano Mourão
Capitão Eduardo
Horto Florestal
Passagem
Belo Horizonte
Vitoria
Tres Rios
Rio de Janeiro
Barra Funda - São Paulo
Santos
GAUGE
0.76 m
1.00 m
1.60 m

Fig. II-5

to resort to truck transportation. Similar examples can be found for other commodities.

(b) Capitao Eduardo - Minas Gerais.

This yard handled the most transfer freight in 1973 with 418,800 tons. The transfer operations are totally mechanized and the holding time for freight cars averaged 2 days. Most of the traffic consists of steel products directed to Sao Paulo. With the implementation of the National Steel Plan, this yard will have to handle a much larger traffic than it is actually prepared to. Already some steel products are being moved by trucks to avoid delays at the yard.

(c) Tres Rios - Rio de Janeiro.

Although there are no figures available as to the average time the freight cars spend in the yard, this yard is probably the best equipped for the interchange operations, and in 1973 handled almost 215,000 tons of freight.

(d) Horto Florestal - Minas Gerais

This yard sometimes handles traffic destined for the Capitao Eduardo yard when it becomes congested. In 1973, 75,600 tons of freight were transferred in this yard, which reportedly averages one day of car holding time. This report, however, is probably optimistic since a petrochemical industry which uses the yard claims a 200% increase in the estimated total transport time of its products due to delay in the yard.

(3) Aureliano Mourao - Minas Gerais

This yard is the only interchange point between the 0.76 m gauge and the 1.00 m gauge and serves basically a cement industry. In 1973, it handled almost 75,000 tons of freight transferred without any mechanical equipment.

The five yards above are the most important in terms of volumes of freight. Nonetheless, many others exist, notably at the border with Argentina and Uruguay, accounting for a considerable amount of freight transferred usually by manual operations.

(2) Change of Trucks

The only yard in Brazil equipped with a truck-changing installation is located in Sao Paulo. The Passagem yard, as it is called, handled 90,800 tons of freight in 1973. Its equipment consists of 2 sets of hydraulic jacks which lift 2 freight cars especially modified for that purpose. The whole operation takes approximately 25 minutes, but no information is available as to the time for which the freight cars are actually held in the yard.[33]

(3) Mixed Gauge

The mixed gauge, with a third rail, is used only as a local solution, over small extensions of line, to provide access between certain terminals, especially in the Belo Horizonte area. On the whole there are no more than 100 km of mixed gauge which represent an unsignificant percentage of the total network.[34]

As we can derive from the description of the several alternatives used in Brazil to overcome the problem of different gauges, this situation poses a series of obstacles for a good railroad service. It increases trip time, makes delivery less reliable and increases the probability of loss and damages due to the additional handling of freight, as well as increasing total costs to the shipper. The examples cited for

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[33] Ibid.
[34] See [8].

the several shippers who were drawn away from the railroad due to this problem make it clear that the set of solutions used, such as freight transfer, truck changes, and mixed gauges, has not been performing satisfactorily. Although there are no reliable figures concerning the total amount of freight interchange due to gauge break points, by a rough estimate based on the yards studied, we can assume that that number does not exceed 10 percent of the total freight carried. However, far from implying that this reduces the importance of the problem, it means that shippers avoid sending by the railroads to keep away from the costly gauge break points, choosing instead the truck, which results in an inefficient allocation of resources. Furthermore, the gauge break points have changed the characteristics of demand for rail, reducing the average length of haul of commodities and thus preventing the railroads from achieving substantial economies of scale with long and heavy shipments which compensate for their higher terminal costs.

Summarizing, the different gauges are indeed a problem because they draw shippers away from the railroads and prevent the more efficient use of the basic railroad characteristics. It can also be noted that gauge break points result in an inconvenience for long passenger trips, adding to the problems of providing a good passenger service. In the final chapter a series of recommendations is made to overcome this problem.[35]

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[35] For an example as to how shipments are affected by gauge breaks, refer to pages 100-101.

CHAPTER III

PHYSICAL NETWORK

A. Fixed Property

The purpose of this chapter is to analyze the condition and maintenance of the railroads' fixed property and identify the effects these could have on the overall operating and economic characteristics of the railroads in Brazil.

Since the standards and practices followed by the Sao Paulo Railways and the condition of various features of way and structure are similar to those of the Federal Railway Network, the same analysis and comments will apply to both.

Substructure

The subgrade or roadbed foundation on much of the network is rather narrow. On 1.00 m gauge lines, this is frequently as little as 3.6 m and in excavated areas it is often reduced by the ditch section, which itself is narrow.

The subgrade material, when not rock as in ledge cuts, consists of sandy and rather solid earth, held together by a small amount of clay, so that excavations are frequently made with a 1:1 or 1:2 or even steeper slope, yet porous enough so that water does not stand on it but drains rather quickly. However, prolonged rains sometimes saturate and erode slopes, causing serious line blockages. Drainage in the roadbed section is accomplished through track-side and berm ditches or masonry gutters on the side and extensive use of cross drains or culverts.

Track Structure

Most of the present ties are untreated hardwood. There are also some softwoods, treated and untreated, a few remaining steel ties, and recent installations of concrete crossties.

Quality of tie timber is deteriorating and the areas of large production are gradually moving away from the railroads. A few tree farms exist and are growing eucalyptus trees for ties, because of the desirable characteristics of this wood.

The treatment of wood ties, with the exception of a few dip treatment plants, is a relatively new practice and only recently several modern pressure treatment plants have been installed. They are designed for use of creosote but the shortage of this material has caused most of the plants to change to salt treatment. The effect of this treatment will not be realized to any substantial degree for several years.

Also, rapidly increasing costs have resulted in reductions in the renewals during the past few years, so the general condition has deteriorated.

Much of the rail on the main tracks is in only fair condition. This is due to a number of factors, primarily the lack of new rail for replacements. In addition, the lack of adequate ties and ballast, poor joint connections, lack of tie plates and anchors, insufficient use of track lubricators, poor maintenance of rail ends, and inadequate line and surface maintenance have contributed to this condition.

Rail is purchased from Volta Redonda - Rio de Janeiro, the only rail-rolling mill in Brazil, or from foreign sources, such as the United States, Poland, or Yugoslavia. Usual weights are 57, 45, and 37 kg per meter, the first and last weights being standard for 1.60 m and 1.00 m gauge, respectively.[1]

Other track material, such as tie plates, angle bars, and spikes, are either sparingly used or in poor condition. Switches are usually shop-made, open earth, and nonreinforced.[2]

About 37 percent of main track is ballasted with good graded stone. About 35 percent is ballasted with ungraded stone that is almost impossible to work effectively with machine tools.[3] Most of the remaining track (28 percent), is ballasted with earth, which is a poor material for handling heavy, fast-moving trains. When dry it is extremely dusty and when wet it is muddy and unstable.

Improvements in ballast are needed to provide a more solid track structure, to permit mechanized maintenance and higher operating speed and to decrease costs.

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[1]These weights correspond to 115, 91 and 75 pounds per yard, respectively. See [4].
[2]See [3].
[3]See [7].

The 1.00 m gauge trackage is barely adequate to handle the volume of traffic now offered. It is not in a condition to permit increased speeds and greater axle-loads, both of which are required for a more efficient operation. Rails, ties, ballast, surface and alignment require considerable upgrading. The maintenance is only minimum and inefficiently performed by hand labor. The lack of an adequate replacement program of track fastenings is a serious detriment and prevents a needed improvement in the general condition.

The 1.60 m gauge lines are generally in better condition than those of the 1.00 m gauge.

The condition of tunnels is generally good. The bridges and trestles, excepting the new ones, are generally in fair to poor condition, especially on narrow gauge lines where serious problems have occurred with the intensification of traffic.

B. Communications, Train Control and Signals

Introduction

This section analyzes the communication, train control, and signalling systems which are used in Brazil and which are so vital for the efficient and safe operation of the railroads.

These systems are similar on both federal and Sao Paulo railroads and consequently are discussed together.

Communications

The fundamental communications system on most of Brazilian railroads is the manual telegraph. In some instances, in the lighter traffic areas, it is the only means of communication. On the lines with more advanced equipment it remains useful as a back-up system.

Another system used is magnetic telephone which is particularly suited for limited range telephone communication. It involves ringing stations by code impulses generated by the calling station. Its advantage over telegraph lines is in the facility offered for voice communication and the lesser dependence on trained telegraphers for this service.

On most of the railroads, the selective telephone is also used. There are generally fair to good lines from the voice quality standpoint. They involve direct contact of stations with the train dispatcher or controller, who can in turn ring any station on this control line. The selective telephone line is the means by which the dispatcher can keep in touch with the progress of trains and instruct station personnel as to the action to take in the case of deviations from scheduled meeting or passing points.

Train Control and Signals

Prior to the installation of a comprehensive signal system in the Rio de Janeiro suburban lines, at the time of its electrification in 1937-1938, signalling on Brazilian railroads consisted of a few mechanical interlockings and manual blocking of trains between stations. Trains were authorized to move from station to station by a written block order, involving the concurrence of operators at both ends of the block who authorized, on paper, the train to enter the block, or by being issued a staff governing the use of the block. Under this system a "staff" or token is the tangible evidence of right to use the block. Electrical circuits and mechanical devices prevent more than one staff being absent from a matched pair of devices, one at each end of the block.

Movement control by means of the telegraph or train staff method still dominates the operation pattern with about 82 percent of the lines operated by the the telegraphic license method, 14 percent by the more positive electric train staff method and only four percent by systems where wayside signals convey authority for movement through a block.[4]

The first use of automatic block signalling in Brazil was in connection with the Rio de Janeiro suburban project. Its use, however, has been limited to their function as elements of the Centralized Traffic Control (CTC) system or use in combination with a series of interlockings to achieve much of the same type of operation as is provided with CTC.

The CTC itself was first installed in Brazil in 1945 on the former Central do Brazil Railroad, covering 495 track-kilometers. This form of signalling

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[4]See [3] and [15].

is a combination of automatic block signalling, interlocking and communications systems, which makes it possible to operate trains between a large number of stations from a single control machine. Economies of equipment and manpower utilization, as well as maximum capacity of trackage, can be expected especially on high density lines.

Planning for more intensive use of CTC began in earnest about 1957 when an Eximbank credit to the former Santos - Jundiai (RFFSA - 9º Division) for rehabilitation of the property included a substantial allotment for a completely modern signal system.[5] Later investments on signalling systems have been made, mostly relying on such foreign exchange credits.

Conclusion

With respect to both signal and communicating systems, we could consider that, in the light of the present low density of traffic on many of the lines, the systems in general would be fairly adequate, if they were properly maintained and supervised, which they are not.[6] The use of an excess number of men,

[5] In 1973, there were 821 km covered by CTC on both federal and Sao Paulo railroads. See [15].
[6] See [3].

not always properly trained, aggravates the communications and train control problems.

However, a definite upgrading will be necessary for any large increase in traffic as is expected, or for a substantial improvement in the overall speed and reliability of train movements.

CHAPTER IV

EQUIPMENT

This chapter describes and evaluates the motive power, rolling stock, and equipment maintenance of the Brazilian railroads.

Motive Power

The number, type, and percentage distribution of the locomotives of the Brazilian railroads in 1973 is given in Table IV-1.

The fleet of diesel locomotives is in general low-powered equipment, as the average horsepower per unit in 1973 was 1,060 HP for the federal network and 998 HP for the Sao Paulo railways. Also the electric locomotives have a low average horsepower, 2090 HP

	Federal		Sao Paulo	
	Units	%	Units	%
Locomotives	1,439	100	517	100
Steam	116	8	-	-
Diesel	1,248	87	352	68
Electric	75	5	165	32
Railcars	379	100	158	100
Diesel	34	9	22	14
Electric	345	91	136	86

Table IV-1 [15]

for the Federal network and 2301 HP for the Sao Paulo railways.[1] The high percentage of low-powered equipment has not permitted an increase in train loading, resulting in low ton-kilometer per train-kilometer ratios.[2]

The few steam locomotives left in 1973 are only used on branch lines and for work train service. They are gradually being retired.

[1]See [15].
[2]See Chapter V, Section B.

Due to the lack of more precise information, the only measure of the actual condition of the locomotives that can be obtained is the ratio of serviceable locomotives to the total number of locomotives owned. This ratio would include not only an appraisal of the equipment itself but also of the quality of maintenance provided, (see Table IV-2).

Those ratios are acceptable by American or European standards[3] except for the diesel locomotives of the Sao Paulo railways.

	Serviceable locos/Existing locos		
	Steam	Diesel	Electric
Federal Network	.61	.88	.85
Sao Paulo Railway	—	.63	.79

Table IV-2 [15]

[3]The AAR reports that for the United States the ratio of serviceable to total locomotives is 0.94 and 0.86 for locomotives on freight service and passenger service, respectively. See [34].

However, an additional maintenance problem results from the number of different types and builders which makes the stocking of parts difficult, increasing out-of-service time and inventory costs.

The railcars are mostly used on commuter lines and are considered to be in bad condition, requiring a considerable amount of work to restore them to proper condition.

Rolling Stock — Freight Cars

The number and type of freight cars owned by the Brazilian railroads in 1973 is given in Table IV-3.

Type	Federal Network	Sao Paulo Railways
Box	15,030	9,709
Gondola	8,342	2,303
Flat	3,955	1,691
Others	6,112	2,890
Total	33,439	16,603

Table IV-3 [15]

The average freight car capacity in tons for each of the two systems is 34 tons for the Federal and 39.6 tons for the Sao Paulo Railways.

Since no figures on the number of freight cars per gauge is given for the Federal Network, only the Sao Paulo data can be used to evaluate the different capacities of the cars operating on the two gauges, 1.00 m and 1.60 m. The average capacity in tons for the 1.00 m gauge was 38.8 whereas the 1.60 m gauge equipment showed an 8.5% larger capacity of 42.1 tons.[4]

These figures can be considered low because the average for the Mexican railroads with a 1.435 m gauge was 52.4 tons,[5] almost 25% larger than the average for 1.60 m gauge Sao Paulo freight cars. Much of course depends on the mix of car types. However, using again the Mexican statistics we can see that the average capacity per flat car in Mexico is 51 tons, still 24% larger than for 1.60 m gauge equipment in Sao Paulo. This low capacity of freight combined with the low horsepower of the locomotives may be expected

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[4]See [15].
[5]Ibid.

to negatively affect the operation of the railroads.

There is, however, an improvement regarding the design of the freight cars. More and more cars are being especially designed for the service in which they are used, thus attending the needs of shippers for specific types of cars.

As was done for locomotives, an appraisal of the condition of freight cars can be obtained through the ratio of serviceable to total freight cars, which, in 1973, was 0.92 for the Federal Network and 0.91 for the Sao Paulo Railway Co.[6]

There was formerly a large diversity of couplings and brakes, but by 1975 they were all standardized.

Rolling Stock — Passenger Cars

In 1973, the number of passenger cars, including coaches, sleeping, dining, baggage, and express cars, and others, amounted to 2,433 for the federal network and 978 for Sao Paulo with an average capacity of 59.6 and 62.0 passengers, respectively.[7]

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[6]Ibid.
[7]Ibid.

The ratio of serviceable to existing passenger cars comprising the fleet was 0.85 for the federal and 0.77 for the Sao Paulo railroad. These ratios are among the best in Latin America.[8]

Maintenance

The maintenance policies and facilities for both the Federal network and the Sao Paulo railways are very similar and will be discussed together.

The major deficiency in maintenance facilities in Brazil is probably the multiplicity of shop facilities found.[9] There are too many small shops which lead to higher costs and poor utilization of manpower, machinery, and space. There is also an excessive amount of manufacturing in the shops which sometimes causes the repair work to be relegated to a secondary position. This originated when Brazil did not have sufficient private industry to meet the railroads' requirements and still continues even though private industry has expanded.

[8] Ibid.
[9] See [3].

There is no definite maintenance problem for freight and passenger cars. Usually the equipment is simply inspected in depots and freight yards and the cars are sent to the shops based on the car inspection reports.

Only the inspection and repair of diesel and electric locomotives and railcars are regulated by predetermined programs, based on kilometrage or time in most cases, in accordance with the builders' recommendations.

As a consequence many accidents are caused by equipment failure and the Federal railroads estimate that 20% of total accidents in 1973 were due to the poor condition and maintenance of equipment.

CHAPTER V

OPERATING POLICIES

A. Operation of Stations, Yards, and Trains

The previous chapters have dealt with various aspects of the plant and equipment used in railroad transport, including their condition and the facilities employed in their maintenance. Under normal conditions of railroad operation, the costs of maintenance of structures and equipment combined are frequently less than the cost of operations. It is particularly important, therefore, that any railroad rationalization effort include an analysis of the methods employed in operating stations, terminals, and trains.

As has been stated before, the lack of adequate information makes that analysis particularly difficult. As a consequence, we have had to resort to personal experiences and contacts to fill this gap. In many cases, no distinction can be made between the two railroad systems and sometimes older data is extrapolated to present days. Nevertheless, we believe that a fairly accurate picture of the situation was delineated.

Station Operation

An on-line station is defined as a point where trains stop for discharge or loading of freight or passengers but is not a point to which switch engines are normally assigned.

In 1973 there were 3498 on-line stations in service on the federal and state railway systems.[1]

One of the important factors in considering the number of stations is the average number of kilometers separating them. For the federal system we have an average of 12.0 km and for Sao Paulo 10.5 km.[2]

An important problem contributing to the operational difficulties of both networks is the design

[1]See [8].
[2]Ibid.

of on-line stations, because most stations have passenger platforms located on a passing track instead of on the main track, thus assuring low passenger train speeds.

Terminal Operation

A fact recognized by railroad men in all parts of the world is that railway yards present a greater number of serious problems than any other facet of rail transportation. Terminals are probably the greatest cause of service delays, unreliability of trip times, and reduced utilization of freight cars, consuming large amounts of both locomotive power and manpower. One of the greatest improvements in railroad operation in other countries, including the United States, has been the concentration of terminal work in newly designed, modern terminals with the consequent elimination of many smaller terminals with poorer facilities.[3]

In 1973, there were 226 switching yards in Brazil[4] and in 30% of these there was only one switching shift per day.

[3]See [27].
[4]See [3].

The average number of switching locomotive-hours per 1,000 freight car-kilometers was one hour and 56 minutes. The corresponding figure for the United States was 48 minutes, or less than one-half.[5]

One of the most serious deficiencies in the design of the larger terminals is in the facilities for the loading and unloading of freight by shippers and consignees. Team tracks, especially in the larger cities, are frequently in the downtown area where there is no opportunity for expansion. Access by both railroad and private truckers is via the most congested highways of the city (Rio and Sao Paulo). This results in poor utilization of the trucks used for picking up and delivering freight at the place of business of shippers and consignees, and results in much poorer service to the shipping public.

Another serious deficiency is the lack of private sidings to manufacturing establishments. These would provide better service to large shippers and help retain traffic for the railroads. With the growing number of manufacturing establishments on the

[5] Ibid.

outskirts of the cities it would be far better to provide separate facilities for large shippers, especially since piggy-back service, which could help alleviate this problem, is still not widely used due to the narrow gauge equipment which makes it unsafe.

Freight Yards

Freight yards are a major deficiency of the railroads in Brazil, due mostly to poor location and design, to failure to modernize as required, and to poor organization and supervision.

Many yards have main tracks and highways dividing them. There are no classification yards of modern design. Several yards still operate with antiquated steam locomotives. Switching is limited almost entirely to that generally termed flat switching. Under this method, cars are pushed to or pulled from tracks by locomotives. The cars for each track are cut off as required and the same procedure continues until the entire group of cars has been disposed of. With the exception of the terminal at Presidente Altino, there are no modern gravity switching yards which provide much faster movement of cars through yards. Classification of freight cars is practiced on several yards, but these are not properly blocked for proper positions in outgoing trains. Rather, it consists of classification of cars by direction to be taken in the next movement.

The interchange of cars between the two systems is an additional problem to freight terminal operations and creates serious delays.

The gauge difference also requires the interchange of freight between lines of different gauges; this problem occurs in 31 yards. This is discussed in more detail in Chapter II, section F and in Chapter VIII.

Passenger Terminals

On the federal railroads there are 39 main terminals, three intermediate terminals and 43 major stations. On the Sao Paulo network there are 21 main passenger terminals, two intermediate, and 32 major stations.[6]

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[6]The definition of main terminals, intermediate terminals, and stations is done somewhat arbitrarily. The difference between main and intermediate terminals is one

Perhaps the most important single problem in passenger terminals is that caused by the lack of supporting a coach yards. This makes it necessary that the formation of trains and servicing of cars be performed within the terminal itself. Because in most of the major terminals there are also movements of freight trains and suburban trains, the result is a succession of serious delays which adversely affect passenger service.

Train Operation

(1) Freight Trains

Freight train operations consist of both through and local types.

Local freight trains operate mostly under the collector concept, under which loaded and empty cars are picked up and distributed at any of the on-line stations, working to and from stations and freight yards, where switching locomotives are employed to prepare cars for through trains.

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of scale, whereas stations are defined as points where trains stop for the discharge or loading of passengers but are not points to which switch engines are normally assigned, contrarily to terminals.

Through direct freight movements are employed primarily to haul bulk commodities such as iron ore, cement, and coal, but for distances over 300 km, mixed commodities trains are also used.

The majority of the through freight trains make a limited number of stops to pick up or set off cars and are scheduled on a regular basis. An important restriction, however, placed upon the operation of through trains is the gauge break points which were discussed in detail in Chapter II.

For an evaluation of train scheduling and movement in Brazil, an average commodity movement has been selected in which a carload of freight is moved from Rio de Janeiro via the shortest route to Porto Alegre in the south of the country. The route covers approximately 2,772 km, encompassing both federal and Sao Paulo systems, 1.00 m and 1.60 m gauge track, with the required interchange of freight and cars.

Table V-1 indicates the type and time of delays encountered under normal conditions.

Adding 129.3 hours of running time to delay times listed would give an average speed of only 12.1 km per hour. As we can see, the interchange of cars

Type	Hours
Interchange of cars	36.2
Yarding and switching	28.0
Interchange of freight	15.0
Tonnage rating change	8.2
Train inspection	5.1
Scheduled stops	4.0
Crew change	2.0
Locomotive change	1.0
Total	99.5

Table V-1 [3]

and freight are the most severe types of delay, accounting for more than half of the total delay time, and can be attributed respectively to the existence of separate railroad organizations and the gauge problem.

(2) Mixed Trains

Mixed trains on both the Federal and Sao Paulo networks are utilized principally to provide passenger and freight service to lower activity stations and on branches, but account for only 8% of total train-km on the federal railroads and 2.5% on the Sao Paulo railroads.

(3) Passenger Trains

The service offered by this type of train is a simple variety and includes, generally, first and second-class passenger cars, a baggage car, and occasionally, on long-distance trains, sleeping and dining cars.

Several types of service are provided, mainly between the major cities and state capitals. These include deluxe and night trains, passenger trains, and commuter trains (Rio de Janeiro and Sao Paulo).

The overall performance of the passenger service, however, is generally very deficient and it is this low quality of service that is drawing passengers away from the inter-urban service while only the low rates maintain ridership on suburban lines, most of which can be considered captive anyway.

Truck or Trailer Train Service

This type of service is commonly known as piggy-back. However, in contrast to the practices followed in Europe and the United States, where only highway semi-trailers are transported on flat cars, in Brazil trucks or complete tractor-semitrailer combinations are loaded on railway cars and accompanied by the drivers. Sleeping cars are provided to accommodate drivers.

This service originated with a contract between a trucking company and the railroad, with the latter supplying a train for which the contractor paid a flat sum for the entire movement. The service was between Rio and Sao Paulo (504 km). Today the service is provided without the middleman and has been expanding. The rates have been established on the basis of the railroads' estimate of the cost per train and apparently without regard to the value of service rendered. The value to the trucker is evidenced by the fact that some truckers have waited a full day in order to use the service.[7]

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[7]See [3].

There is, however, little movement of semi-trailers without power units and drivers [2] as is done elsewhere, and no attempt has been made to establish a service using railroad-owned highway equipment or to implement the movement of containers along the railroad. This is another evidence of the lack of aggressive commercial policy by the railroads in competition with the trucks.

The Accident Record

The number of accidents is quite frightening, constituting another major adversity for the quality of service given to the shipper or consignee.

The figures show a total of 9,154 accidents for the federal network and 1,540 for the Sao Paulo railroads in 1973, involving collisions and derailments and excluding other accidents with materials in general.[8] This means that for every day of the year, there were 25 railroad accidents in Brazil with an average of 92.3 and 50.8 accidents per million train-kilometers for the federal and Sao Paulo systems, respectively.[9]

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[8] See [15].
[9] Ibid.

While statistics which are comparable and covering operations elsewhere are not readily available, there is no doubt that this represents an extremely poor record and that more study as to the causes of accidents and action to eliminate these causes are urgently demanded.

B. Operating Performance

In Section A, we have analyzed the method of operation of the Brazilian railroads. In this section, we will look at the operating performance in terms of operating efficiency and equipment utilization.

The methodological approach to this section was to select a set of relevant parameters for each case and to compare them with what can be considered good levels of performance. The yardstick used was the Southern Railway System, one of the best performing U.S. railroads and one having a comparable route-kilometrage and network deployment.

The parameters chosen and their 1973 values for the federal, Sao Paulo, and control railroads are shown in Table V-2. The federal system was divided into its 4 regional systems because they have various degrees of operating efficiency and this would provide a useful insight into their different characteristics.

The Brazilian figures, both in terms of operating efficiency and equipment utilization, are generally well below those of the control road. There are also noted differences within the federal system with the Central Regional System consistently reaching

Operating Characteristics	North-East	Center	Center-South	South	Sao Paulo	Southern
	Federal Railway System					
Efficiency						
Traffic Density	158,000	1,052,000	781,000	518,000	685,000	4,253,000
net ton-km/route-km/year						
Traffic Frequency						
train-km/route-km/year	1,166	4,452	5,616	2,024	2,656	2,482
Train Loading						
net ton-km/train-km	225	543	269	416	257	1,715
Locomotive Units per Train	2.0	2.8	2.1	2.1	2.6	3.1
Freight Cars per Train	10.1	24.9	20.8	16.6	15.6	67.5
Utilization						
freight car cycle time	13.6	8.0	10.3	11.7	10.8	8.6
car-km/serviceable car-day	36.7	90.2	40.3	40.6	39.9	101.0
ton-km/serviceable car-day	817.8	1966.7	520.3	1020.7	658.3	2576.0
net ton-km/loaded car-km	28.3	32.1	30.2	29.2	21.8	44.8

Table V-2 [7,15]

higher levels than the rest. In terms of equipment utilization, its performance approaches that of the control road. It does, however, have a shorter average length of haul which normally leads to smaller cycle times. Of all the systems, the North-East system clearly shows the worst performance with the South system somewhat better than the Center-South. All the Brazilian systems, including the Sao Paulo system, operate short trains with an average of more than two locomotives per train, which clearly denotes what has been noted previously about the low horsepower of the Brazilian locomotive fleet.

We can then summarize the general operating characteristics of the Brazilian railways as follows:

(1) Generally low density of traffic, especially in the North-East.

(2) Short trains with small average loadings.

(3) Generally high freight car cycle times, especially in fiew of the short average length of haul, indicating poor car utilization with the possible exception of the Central System of the Federal Railways, which shows somewhat better levels.

CHAPTER VI

PERSONNEL POLICIES

For many years the transport sector in Brazil has been used by politicians to strengthen their political support by rewarding political followers with jobs in government-owned transport companies, such as the railroads. These individuals, of course, seldom contributed to the running of the railroads and sometimes came to work only to collect their pay checks. Government labor regulations had all but eliminated the possibility of firing such employees and the staffs of most publicly owned railroads became exceedingly large, as we shall see later.

A second method of securing political support was to raise the wages of those working in the transport sector, which constitute a large number of voters. Between 1945 and 1969 an index of real mean annual expenditures on personnel per employer rose from 100 to 26,166 for industry, but for the railroads rose from 100 to 64,688, i.e., 147% more.[10] In the early 1960's a station agent for a medium sized railroad station received a higher salary than a Justice of the Peace or a regional police chief.[11]

As of 1973, the Federal Railway Network employed 112,806 and the Sao Paulo Railway Co. 26,349 people.[12] Their distribution among the major functions was as follows:

	Federal	Sao Paulo
General Administration	17.6%	18.9%
Movement and Traffic	32.3%	30.3%
Traction and Rolling Stock	19.0%	32.6%
Fixed Installations	31.1%	18.2%

Table VI-1 [15]

[10] See [14].
[11] See [31].
[12] See [15].

There has been in recent years a significant decrease in railroad employment (see Figure VI-1). Since 1964 when the new federal government started showing concern as to the number of railroad employees, their decrease was substantial (26%), while the decrease on the Sao Paulo railroads over the same period was even more significant (41%).[13]

In addition to the above listed forces, moreover, the railroads use a large amount of contract labor, not only for construction but also for maintenance and repair within main and auxiliary shops and in other services. This is used as a means to fulfill temporary personnel needs without incurring the social benefits required for regular employees. In many cases, these forces work alongside and participate in the same work as regular railroad employees, a fact which prevents the use of effective measures of cost and quality control.

Labor Legislation

The labor forces of the federal system are affected by two different types of legislation which

[13] See [1].

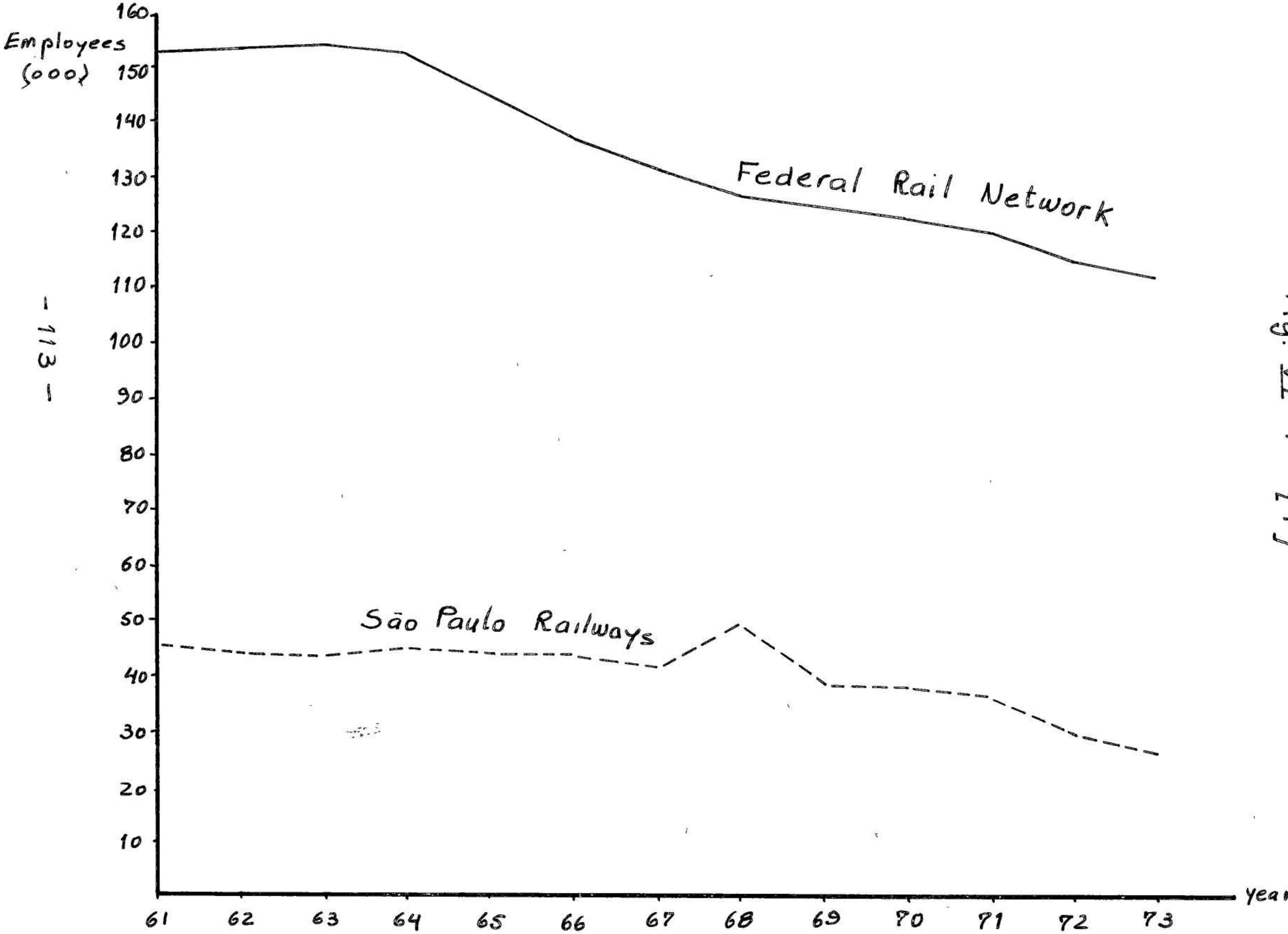
Employees (000)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Federal Rail Network
São Paulo Railways
year
61
62
63
64
65
66
67
68
69
70
71
72
73

Fig. VI-1 [1]

provide for different social benefits, working conditions, and other factors which prevent the most efficient use of manpower.

The two groups of employees affected are: firstly, those who were employed on all federal railroads and transferred to the RFFSA in 1957 with all their prerogatives as civil service employees; and secondly, those hired by the RFFSA since 1957 who are governed by the same legislation covering employees in industry.[14]

The major differences concern

(a) dismissal: civil servants only are dismissed by the Minister of Transport acting on behalf of the President of the Republic, for proven gross misdemeanor, whereas industry employees can be dismissed without appeal with the due compensation;

(b) overtime: industry employees receive a much higher rate;

(c) unions: civil servants cannot belong to a union;

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[14] See [9].

(d) transfers: civil servants cannot be transferred to other localities during a period of six months before or three months after federal or state elections, making forced transfers virtually impossible.

It can be appreciated from the foregoing that the simultaneous existence of these two systems, involving different work rules, social benefits, disciplinary action and scales of pay, has been a major reason for a personnel condition involving excess numbers, low production, dissatisfaction on the part of employees, and operating difficulties.

The Sao Paulo railroads, fortunately, are governed by a single legislation concerning the railroad statutes of the State of Sao Paulo.[15]

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[15] Detailed data concerning, for instance, union membership, overtime, and transfer, were not available due to the changes which occurred with the unification of the Sao Paulo railroads under a single organization in November 1971.

Labor Costs

In 1973, labor costs surpassed total revenues in the Northeast system by 85% and in the Sao Paulo railroads by 3%, while they equalled revenues in the Center system. Only in the Center-South and South did labor costs remain at somewhat more satisfactory levels.[16]

It is interesting to note that in spite of the decrease in the number of employees shown in Figure VI-1, the percentage of labor costs to total costs has remained reasonably constant for the last year. Table VI-6 shows that no decreasing pattern can be clearly identified in labor's share of total costs.

Productivity Measures

To measure productivity of personnel the most relevant parameter is the number of employees per traffic unit (ton-km + pass-km).

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[16] These levels can only be considered satisfactory by comparison with other developing countries (see [34]), because for U.S. railroads labor costs account only for 35% of total operating expenses (see [33]).

In 1973, the federal system showed 5.1 employees per million traffic units and the Sao Paulo railroads 4.3.[17] These measures are low if compared for instance to Mexico which only shows 3 employees per million traffic units. The trends, however, indicate that there has been a steady improvement over the last years.

A trend analysis of the number of employees per million traffic units with origin in 1965 (Y)[18] showed the following results:

Federal $Y = 7.032 - 0.207X$

Sao Paulo $Y = 7.175 - 0.350X$

where Y = one year unit.

This signifies that the Sao Paulo railroads have had a slightly higher rate of improvement in productivity since 1966.

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[17] See [15].
[18] See [7] and [16].

CHAPTER VII

PRICING POLICIES

Introduction

Historically, the Brazilian railroad freight rate schedules have been based on the value of service concept following more or less the general pattern found on railroads throughout the world. What this means is that instead of rates reflecting the actual transport costs of the various commodities transported, each type of traffic was charged at a rate based on what it was considered the traffic could afford to pay. This system of price discrimination evolved for several reasons. Firstly, while the railroads had a virtual monopoly of inland transportation it was the most profitable method of pricing. Secondly, it was used as an instrument of economic policy to promote the development of certain regions or industries. Thirdly, it was used because of the difficulty of determining actual costs for the several types of service. This method of pricing served its purpose up to a certain point in time. As the railroad administration remained indifferent to growth of road competition, this system of rating became increasingly inappropriate, and proved to be a serious handicap for the railroads. The existence of differential rating made the railroads particularly vulnerable to this new competition as the rates on high value goods were above those required for a normal profit by truckers. Thus the road carriers, through a more flexible rating system, were able to undercut successfully the railroads' rates and capture the market for high rated commodities, leaving the low rated traffic for the railroads.

The loss of high rated traffic not only posed a financial problem for the railroads, as the profit on this traffic was intended to cross-subsidize socially desirable but uneconomic services, but it also led to a misallocation of resources and an increased total cost to society. This occurred when the railroads, because of their rating policies, lost traffic to highway transportation which could have been carried more efficiently by rail than by truck.

Present Policies and Practices

The present uniform tariff policy of the federal railroad network establishes 14 classifications of commodities combined into four rate groups, with four commodities — iron ore, lumber, wheat, and limestone — being given special rates.

The present tariff combines in the same rate group commodities exhibiting great differences in rolling stock requirements, terminal conditions, weight, size, bulk, and value. Thus, Group I includes shoes, bicycles, and gasoline, Group II includes sugar, wine, and road machinery, Group III includes beer, cement, and fresh meat, and Group IV includes bananas, bricks, and coal, among others.[1]

It seems obvious that grouping all commodities into four basic rate levels is an over-simplification which must result in inequities to both the railroad and the shipper. If as a result of improper classification

[1]See [3].

a rate relatively too low is charged, the railroad will be offered a large percentage of the traffic available, with the result that the railroad loses money on that business. If a rate relatively too high is charged, the shipper is penalized or the railroad loses to other modes the traffic which it should retain on the basis of its comparative cost of supplying the service.

Rates in Relation to Cost

The failure of the rate policies to provide for the increases in costs is demonstrated in Table VII-1, which shows the changes of freight rates as compared to those of prices paid by the railroad represented by the wholesale price index. The rates, costs, and prices of 1957 are used as the bases for each index.

Rate Concessions

The managers of the individual divisions are permitted to give rate concessions from the standard tariffs in conformance with standards and limitations established by the Commercial Superintendency of the RFFSA.

Year	Freight Rate[2] (Commodity Class 9)	Wholesale Price Index
1957	100	100
1958	100	112
1959	100	155
1960	102	203
1961	130	280
1962	169	429
1963	329	745
1964	622	1,428
1965	1,066	2,286
1966	1,408	5,437
1967	1,891	8,164
1968	2,394	9,228
1969	not available	10,992
1970	not available	13,108
1971	4,303	15,929

Table VII-1 [14]

[2]Class 9 covers food commodities.

However, flexibility in meeting competitive situations for which this policy is designed is negated, at least in part, because prior approval of the RFFSA headquarters is required before the special agreements can be made effective. This frequently takes so much time that the traffic is lost to other modes.

Passenger Fares

The schedule of fares establishes standard rates for first- and second-class passenger service for one-way and round-trip passage based upon distance travelled. It also includes separate tables for baggage and parcels in two classes with rate reductions permitted up to 50 percent of the standard rate under certain conditions of transport, e.g., unaccompanied baggage.

Non-revenue Traffic

Until 1963, mail in Brazil was carried free of charge by the railroads. Originally, when a grant or concession was given by the government for the construction and operation of a railroad, a clause was normally inserted requiring the concessionaire to transport mail and other government traffic free of charge. The transfer of railroad ownership from the private concessionaire to federal and state ownership did not change this situation.

However, in 1963, a proposal was filed requesting approval of the RFFSA to charge for the carriage of mail.[3] An interesting feature of this proposal was the differential charges for mail over 1.00 m gauge and over 1.60 m gauge, as if the gauges had any influence over the cost of carrying mail. The proposal was approved and this practice is currently applicable.

The Sao Paulo Railway Co.

The Sao Paulo railroads operate under a standard commodity classification guide and schedule of rates and fares published by the Secretary of Transport of the state.[4]

The schedule and classification guide are structured in a way similar to those of the federal

[3] See [3].
[4] Ibid.

system, differing basically in the level of rates charged. Roughly, it can be said that the rates of the Sao Paulo railroads are higher than comparable rates of the federal system for all distances up to 600 km, beyond which distance the opposite situation prevails. Also in passenger service the relation between second- and first-class is lower for the Sao Paulo railways.

CHAPTER VIII

SUMMARY AND RECOMMENDATIONS

A. Summary

This summary will focus on those features which we consider essential for the rehabilitation of the entire Brazilian railway system. The conclusions are based on a premise that such a system is necessary for the efficient functioning of Brazil's overall economy and social organization.

The following are those factors which were found to be the primary causes of the present unsatisfactory situation prevailing on the railroads as documented in the preceding chapters.

Institutional or Organizational Structure

The existence of two networks each under the ultimate control of separate governments, one federal and one state, contributes to inefficiencies of organization in the Brazilian railroads. The situation is made more complicated by the fact that the Sao Paulo network splits the federal system in half, so that much of the north-south long-distance traffic suffers interchange delays, accounting complications, etc. emanating from both networks.

The multiplicity of governmental departments and organizations which, in greater or lesser degree, control, regulate, or influence the operation of the railroads, prevents the appropriate coordination of efforts and policies.

The combination of these factors causes such a fragmentation of both authority and responsibility that no proper coordination of efforts can be achieved and no person or group can be held responsible for the financial debacle which has occurred.

The diversion of investment funds, needed to upgrade existing main lines of relatively high traffic densities, to the construction of new lines of doubtful need and dubious feasibility represents a possible misuse of needed funds. This observation gains particular importance at a time when the government is preparing for a massive investment in the railroad sector.

Personnel Policies

A combination of laws and decrees exist, which prevent full utilization of personnel, compel the railroads to retain excessive numbers of employees and at the same time prevent them from hiring necessary, qualified technical staff with training in modern management and technological skills. Such hiring practices prohibit safe operation and adequate maintenance.

Equipment

Low average horsepower of the motive power has not permitted an increase in train loadings, thus preventing the railroads from taking full advantage of the inherent economy of scale in rail operations.

Diversity of equipment in use complicates stocking of spare parts and increases out-of-service time and inventory costs.

Physical Network

The physical characteristics of the network involve excessive numbers of heavy grades, sharp curves, and poor maintenance of tracks and equipment.

Pricing Policy

Railroad managers lack a pricing system which gives them an aggressive policy in the solicitation of traffic at rates which both compensate the railroad and attract shippers.[1]

Operating Policies

An unnecessary multiplicity of operating and maintenance facilities, such as yards, shops, and stores, inherited from the former railroads, remain in use and decrease efficiency.

Added expense and serious delays are incurred from the large number of interchange points with consequent duplication of switching, car inspection, and paperwork.

Yards are poorly located and designed. Failure to modernize and organize them according to advanced yard specifications preserves inefficiencies of operation.

The Gauge Problem

This problem has drawn shippers away from the railroads and has prevented efficient use of railways in their most efficient application: long-distance shipments of heavy commodities over land.

It could be argued that in the past this did not constitute the serious problem that it constitutes today, simply because the pattern of railroad traffic flow was different. The economy of the country was characterized by several separate points of activity that generated only regional flows, with little inter-regional traffic moving, especially from north to south.

Today, however, these facts are no longer true. The economic development of the country, described in Chapter I, has significantly altered the situation and

[1] In 1975, the RFFSA created a new department of costs which would compute the costs to be used in establishing compensatory rate schedules.

the economic activities of the southeast region, where the gauge problem is most acute, has played a major role in this change. The information given below clearly underscores the importance of the southeast region in relation to the rest of the country.

The southeast covers 11% of the area of the country, with 43% of its population. It provides 81% of the industrial production of the country, 66% of its services, and 40% of its agricultural production. It generates 64% of the national income, which in per capita terms, is 51% higher than the average for the country and 52% higher than that of the second most developed region (the south). In the international trade of the country, it accounts for 83% of exports.[2]

Furthermore, the National Steel Plan, which estimates an expansion of the present annual steel production from 8 million tons to 20 million tons in 1980[3] is projected on the interchange of products within that region alone. For the first time there will be traffic originating at several points reaching levels only paralleled today by the Vale do Rio Doce Company

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[2]See [14].
[3]See [2].

whose private railroad in 1972 carried 27 million tons of iron ore between Vitoria and Minas with a back-haul of 6 million tons.[4]

Until now, when the problem of different gauges was debated in Brazil, the major problem mentioned was the transfer of freight with all of its attendant implications. However, the counter-argument to this was that the volume of freight interchanged between the different gauges seemed to be decreasing or at least stabilizing. In fact, some yards located at gauge break points stopped freight transfer operations. This seemed to indicate that the gauge problem would die out and the railroads would restrict themselves to shorter hauls where no interchange was required. The error of this argument, however, was that the gauge problem was providing itself the answer. That is, the gauge situation made the interchange of traffic so difficult that the volume of traffic requiring interchange was decreasing. This caused truck transportation to fill the gap and capture a share of the freight which would otherwise be carried more efficiently by the railroads.

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[4]See [13].

Now, as the government is seriously engaged in planning for the rehabilitation of the railroad sector, this problem must be addressed by means of detailed cost-benefit studies which will indicate where and how a sufficient degree of gauge uniformity can be achieved to enable the country's rail network to realize its full potential in contributing to the economic development and well-being of the country at large.

We can therefore summarize the two new facts which alter the pattern of rail transport in Brazil, with an emphasis on the southeast region where Rio de Janeiro, Sao Paulo, and Minas Gerais are located:

(1) The new pattern of traffic with high volume, single origin and destination pairs, single item flows which are traditionally rail oriented (steel industry products and inputs)

(2) The new pattern of economic activity, with an increased regional integration, shifting the transportation activity away from the traditional pattern by which raw materials went directly to the various ports for export to new inter-regional domestic flows including those from north to south.

In the first case, the example is the already-mentioned steel industry expansion which is estimated to generate 17.2 million tons of steel to be carried by the railroads and a corresponding 14.6 billion ton-kilometers transport of basic inputs such as iron ore, coal, and limestone,[5] requiring consistent expenditures and reliable performance on the part of the participating operating regions and their personnel.

As an example of what is stated in the second case, a recent study for the Ministry of Transportation[6] estimates for 1980 the following flows from the several production centers in the southeast area, averaging a yearly increase of approximately 8%.

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[5]See [2].
[6]See [6].

Item	Regional Destination	Net ton-km (millions)
Cement	Southeast, South, Northeast	3,100
Corn	Southeast, South	600
Wheat	Southeast	1,000
Soy Bean	Southeast, South	2,000
Sugar	Southeast, South, Northeast	1,100
Fertilizers	All	700
Oil Products	Southeast, South, Northeast	1,700

Table VIII-1 [6]

B. Recommendations

The Gauge Problem

In view of the facts depicted in the previous section, such as the new patterns of traffic flows and economic activity in the Southeastern region, we recommend that the region be served by a standardized network to avoid the gauge break points which would become unsurpassable bottlenecks with the expected traffic expansion.

This implies in the partial standardization of the total network within that strategic region of the country as a first step for the totally unified network. The extension of this standardized network to the other regions of the country should be considered in the fugure when the levels of development in those regions so demand it.

The standardized network in the Southeast region would have the advantage of enabling the use of unit trains, which are perfectly suited for the type of transport mentioned above, as well as it would make possible a much better car utilization since the same freight car could be used throughout the network.

The network proposed should include those strategic lines connecting the three major industrial centers with an extension to the southern region which follows closely the levels of development of the southeast.

The choice of the standard gauge and the economic justification of the network will be the subject of the next sections.

Choice of the Proper Gauge for the Proposed Network

In choosing a specific gauge for the standardized network recommended in the previous section, several factors have to be considered which can be affected by the gauge used:

(1) Technical factors

(2) Cost factors

(3) Neighboring countries

(4) External impacts.

(1) Technical Factors

(a) Dimensions of the rolling stock. It seems perfectly logical to assume a direct correlation between the gauge and the size of the rolling stock.

The larger the gauge the larger would be the dimensions of the railroad cars. In spite of this, however, a closer look at Table VIII-2 will indicate that this is not always confirmed by the actual facts.

In fact, the table shows that:

(1) Ireland with a 1.600 m gauge has lower and narrow freight cars than the Soviet Union with a 1.524 m gauge.

(2) South Africa and Japan with 1.067 m gauges have freight cars with dimensions comparable to those of U.I.C.F. countries in Europe with 1.435 m gauge.

Gauge (m)	Country	Maximum height of freight cars (m)	Maximum width of freight cars (m)
1.600	Ireland	4.267	3.251
1.524	Soviet Union	5.249	3.410
1.435	U.I.C.F.*	4.280	3.000
1.067	South Africa	3.962	3.048
1.067	Japan	4.000	3.000

Table VIII-2 [9]

*Union Internationale des Chemins de Fer

In Brazil the 1.60 m gauge equipment was originally imported and adapted from the 1.435 m standard gauge foreign equipment and, therefore, is not wider than standard gauge equipment. Also it has an average capacity which is only 8% larger than that of 1.00 m gauge equipment while Mexico standard equipment has double the capacity of 0.914 m gauge equipment.[6]

This clearly demonstrates then that the specifications for the size of the equipment were chosen quite arbitrarily by each country and have been kept in most cases by a question of tradition. Therefore, other considerations than gauge dimension, such as cars with two four-wheel trucks, longer cars, etc., have to be taken into account as determinants of freight car capacity.

(b) Dead weight. One of the arguments used by those that prefer narrow gauges is that it reduces the dead weight proportionally to wider gauges. In fact the ratio of tare weight to maximum permissable load is larger for the 1.60 m gauge (0.28) than for the 1.00 m gauge (0.26) for box cars.[7]

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[6] See [15].
[7] See [4] and [7].

However, for the same reasons stated in the previous item, that is, that specifications for equipment size vary quite arbitrarily, as well as the official limits for maximum loads, there is no conclusive evidence to state that gauge dimension influences the proportion of dead weight displaced.

(c) Stability. There are basically three ways by which the gauge chosen can affect the stability of railroad equipment.

(c1) Weight of Rails and Ties

One of the problems for a train to attain good speeds at an acceptable safety level is the lateral bending of rails. However, this effect is countered by the weight of the rails and ties used, i.e., heavier rails and ties lead to less lateral bending. Since wider gauges will require larger and heavier ties, it becomes clear that wider gauges facilitate a more stable circulation of trains.[8]

(c2) Tie Bending

Generally ties are not dried in their central part to obtain two independent supports under each

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[8] See [21].

rail, thus avoiding the likelihood of a high bending moment occurring at the center.[9] Since this is best achieved where the distance between nails is larger, one can say that here as well the wider gauges will provide a greater stability.

(c3) Speed

For the construction of the Japanese railroad line between Tokyo and Tokaido, in which trains attain speeds of up to 230 km per hour, Japanese engineers conducted extensive studies from which they concluded that the speed attained was directly related to the suspension system. In turn, to increase the cushioning capacity of the suspension system beyond a certain point, a wider gauge would necessarily be required.[10]

In summary, all three factors show that wider gauge leads to increased stability.

(2) Cost Factors

In order to evaluate the advantages and disadvantages, costwise, of the various gauges, two

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[9] This practice was described by a DNEF representative at a seminar on railroad engineering sponsored by the Catholic University in Rio de Janeiro, 1974.

[10] See [19].

different cases will be considered:

(a) Lines with the same alignment

(b) Lines with different alignments.

(a) In the first case, there are no differences as to the location of the route and, therefore, for the different gauges; only the excavation and embankment volumes will differ.

The following figure shows a typical excavation section. To obtain an embankment section, the figure has only to be inverted. Therefore, the numerical calculations made for one are valid for the other.

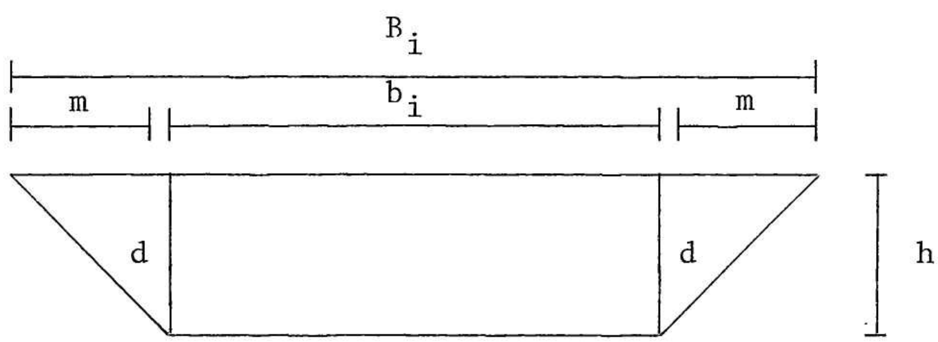

Figure VIII-1

The area of the section is:

$$A_i = \frac{B_i + b_i}{2} + h \qquad (1)$$

Since $B_i = b_i = 2m$, substituting we have:

$$A_i = (b_i + m)h \qquad (2)$$

Noting that $d = \frac{m}{h} = i$ we can write:

$$A_i = (b_i + ih)h \qquad (3)$$

The relative difference (Δ) between gauge 1 and gauge 2 is then given by:

$$\Delta = \frac{A_1 - A_2}{A_2} = \frac{(b_1 + ih)h - (b_2 + ih)h}{(b_2 + ih)h}$$

$$= \frac{b_1 - b_2}{b_2 + ih} \qquad (4)$$

Substituting in expression (4) the official specifications of the Brazilian railroads [4] for a constant height of 10.0 m, the percentage increment of earth work from the 1.60 m gauge to the 1.00 m gauge is:

For excavation,

$$\Delta = \frac{7.20 - 6.00}{6.0 + \frac{2}{3}(10.00)} = 0.095, \text{ or}$$

$$\Delta = 9.5\%$$

For embankment

$$\Delta = \frac{6.10 - 4.90}{4.90 + \frac{3}{2}(10.00)} = 0.060, \text{ or}$$

$$\Delta = 6.0\%$$

We therefore conclude that substructure costs of a 1.60 m gauge line do not exceed those of a 1.00 m gauge line by more than 10% when the alignments are the same.

Considering, however, the track structure costs, this percentage may increase somewhat due to the usually heavier rails, longer ties, and higher ballast of the 1.60 m gauge lines.

Summarizing, for the same alignment, 1.60 m gauge lines can be expected to be 10-20% costlier than 1.00 m gauge lines.

(b) Lines with different alignments.

As we have seen in the previous section, if the location of the routes is the same, there is no great advantage in cost between gauges. However, since narrower gauges permit smaller curves, they can provide large cost savings on a construction project over rough mountainous terrain.

The reason for this is the curve resistance, which is usually calculated by the following formula[11] :

$$r = \frac{500}{R} g$$

where r = curve resistance

g = gauge dimensions

R = radius of the curve

As we can see, for a fixed r, a larger gauge will require a larger radius for the curve leading obviously to more stringent specifications for wider gauge lines. It is difficult, however, to compute the real cost savings, if any, of the smaller gauges because in the end, the smaller gauges will probably lead to longer

[11] See [21].

distances and greater curvatures with much worse operating characteristics.

The conclusion one can draw from the above discussion is that there is in effect a cost difference in favor of the narrower gauge but that the cost difference is offset by operating disadvantages.

(3) Neighboring Countries

In considering a standardized network, a factor to be taken into account is the railroad interchange with neighboring countries. This may not be important when compared to the total volume of freight carried within the country. Nonetheless, it is a factor that should be weighed in the decision, due to the implications that it might have on future plans for foreign trade.

The Brazilian railroad network is connected with those of Argentina, Bolivia, and Uruguay. In the case of Bolivia, there is no gauge problem. Both networks are in 1.00 m gauge and although presently the interchange of traffic between the two countries is of relatively little significance, the connection will acquire a greater importance when Bolivia joins its present networks, thus linking the Atlantic and Pacific oceans, from Santos, Brazil to Arica, Chile. This is expected to occur in the near future, since the World Bank has already loaned the money for construction.

In the cases of Argentina and Uruguay, however, there is a gauge difference since both networks are of standard 1.435 m gauge at the border with Brazil. Therefore the gauge that would be most suited for the interchange of traffic with these countries would be the standard. Nevertheless, it is inadvisable to recommend Brazilian standardization to that gauge solely because of that fact, since the international traffic is of relatively small significance to the Brazilian railroad system and since the 1.435 m gauge represents only 9% of the Argentine network compared to 55% of the 1.676 m gauge and 35% of the 1.00 m gauge.[12] This raises, then, the possibility that the 1.435 m gauge might not be the gauge indicated for the standardization of the Argentine network. Since the traffic with Uruguay alone, without Argentina, is

[12] See [15].

not significant enough, the reasoning for a 1.435 m gauge network in Brazil is invalidated.

The solution required for a connection with Argéntina and Uruguay using 1.435 m gauge would not be suited in turn for the connection with Bolivia's 1.00 m gauge and consequently with Chile and Peru once the above-mentioned link is complete. Further, the international traffic is of little significance to the Brazilian rail system when compared to the national traffic, and Brazil's more developed neighbor, Argentina, also has gauge problems with potentially different solutions.

The recommendation is that the search for a standard gauge should not depend on the gauges in neighboring countries but solely on factors of national interest. The international trade carried by the railroads is not estimated to reach levels in the near future which would justify a standard gauge for Brazil and its neighbors. Therefore, other solutions are preferable, such as freight transfer operations, truck changes, mixed gauges, or increased containerization.

(4) External Impacts of a Standardization Program

This factor relates to the practical aspects of the operation of changing gauges while all other socio-economic activities of the country remain the same.

In the case of changing from the 1.60 m gauge to the 1.00 m gauge, we could expect a lengthy disturbance of the economic activities of the southeast region and consequently of the whole country. In fact, it would adversely affect the two major ports in the country presently served by 1.60 m gauge lines — Rio de Janeiro and Santos —, two of the largest steel industries — Companhia Siderurgcia Nacional in Rio and COSIPA in Sao Paulo —, all the automobile industry located in Sao Paulo, an estimated 30% of the manufacturing industries in Sao Paulo, and the petrochemical complex of Cubatao. The costs of this operation are difficult to measure but are, no doubt, enormous.

Comparative Analysis of the Several Gauges

Considering the factors noted above, we shall now analyze each gauge individually.

1.00 m gauge:

(1) It represents a larger percentage of the Brazilian network (88%), although 4,306 km have their substructure ready for 1.60 m gauge.[13]

(2) Adopting the 1.00 m gauge, the cost of substituting the 1.60 m gauge would be smaller, requiring only that rails be moved closer together over a small percentage of the network (11%) and switches be changed.

(3) It reduces transport capacity due to smaller equipment and lower operating speeds.

(4) Its lines are generally older and would require considerable upgrading.

(5) It has a lower stability, preventing safe piggy-back operations.

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[13] See [6].

(6) 1.00 m gauge locomotives require changes in the original design of standard gauge locomotives, being relatively more expensive.

(7) Wider gauge equipment could not be adapted for use on narrow gauge lines as narrow gauge equipment can be adapted for wider gauges, thus ruling out the use of 134 electric locomotives, 450 diesel locomotives, 875 passenger cars, and 16,049 freight cars.[14]

(8) It would have a highly negative impact on the economic activities of the southeast region if it was adopted as a substitute for existing 1.60 m gauge lines, leading possibly to an economic chaos in the country.

Considering the above factors, it may be argued that the narrow gauge solution can be eliminated quite safely as a potential solution for a standardized network. The choice then remains between the standard and the wide gauges.

[14] See [1] and [15].

<u>1.435 m and 1.60 m gauge</u>:

(1) Both gauges are practically equivalent, considering such factors as construction, maintenance, and equipment costs and technical performance.

(2) The 1.60 m gauge represents a larger percentage of the Brazilian network (11% as opposed to 0.6% for the 1.435 m gauge. Besides the present 1.435 m gauge line is completely isolated.[15]

(3) The choice of the 1.435 m gauge would require a completely new network with new equipment, requiring a much longer time to implement.

(4) The choice of the standard 1.435 m gauge would produce a similar or worse problem as the narrow gauge choice, considering the disturbance on the economic activities of the southeast region.

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[15] See [13].

Conclusion

In view of the above related circumstances, the recommended standard gauge for the southeast network specified in the previous section is the 1.60 m gauge.

C. Economic Justification of the Proposed Standardized Network

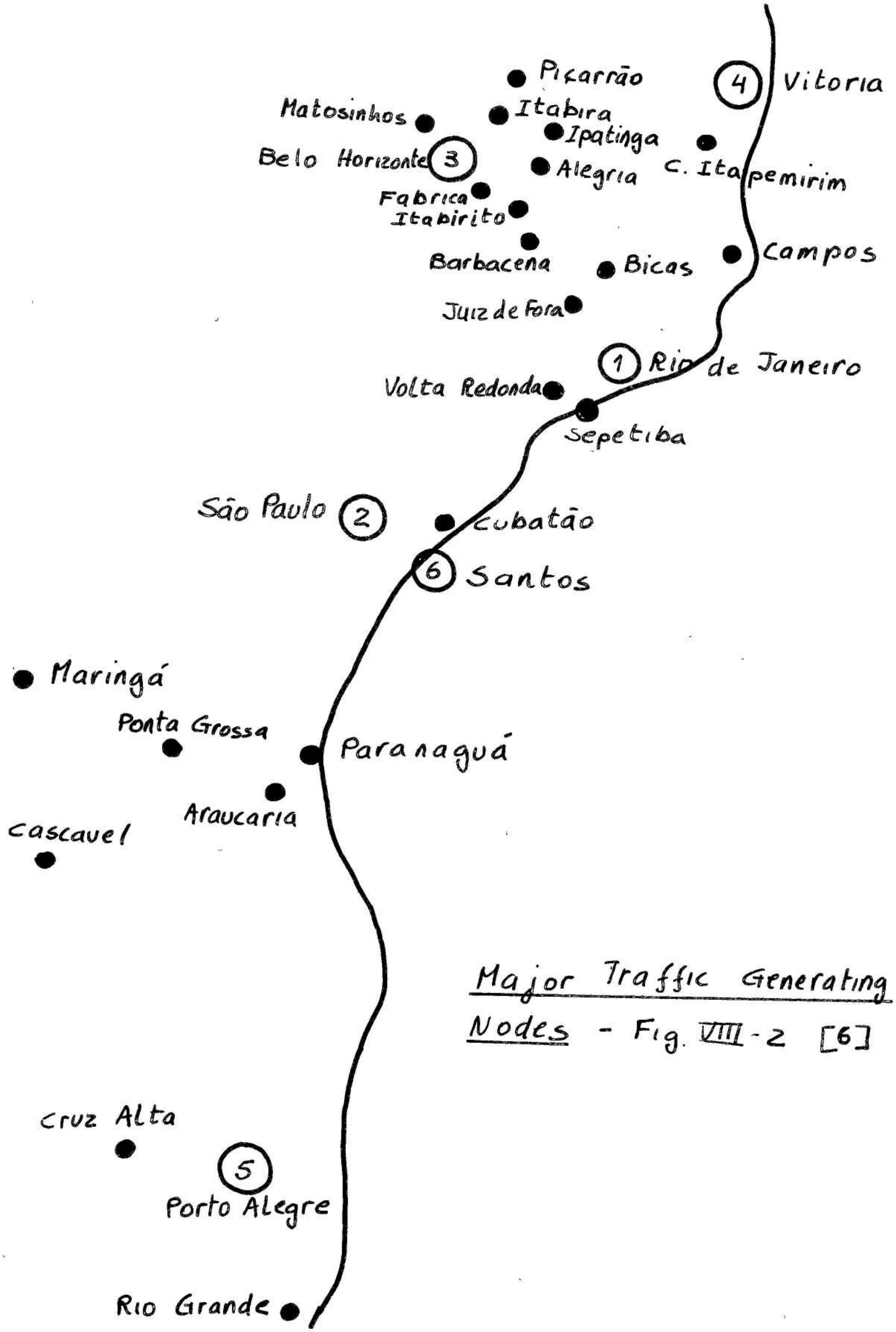
Network Definition

The network proposed in the previous section was vaguely defined as linking the three major industrial centers in the country located in the southeast region with an extension to the southern region. A more precise definition is needed for our purposes in this section.

Figure VIII-2 shows the major freight generating points in the area. From it seven major points or intersections can be determined which would define the several links constituting the network proposed. They are:

(1) Rio de Janeiro
(2) Sao Paulo
(3) Belo Horizonte
(4) Vitoria
(5) Porto Alegre
(6) Santos
(7) Itutinga

From the description of the existing lines between those points, the network can be precisely



Major Traffic Generating Nodes - Fig. VIII-2 [6] defined as shown in Figure VIII-3. It would have a total mileage of 3,826 including 866 km of totally new 1.60 m gauge trackage, 500 km of existing 1.60 m gauge as well as 2,710 km of 1.00 m gauge to be widened and 250 km of projected 1.00 m gauge lines which would have to have their designs changed to 1.60 m gauge.

Costs of Standardization

The only costs considered for our purposes here will be those that can be directly imputed to the standardization proposed herein. This signifies that those investments which were already planned, such as the construction of new 1.60 m gauge lines, cannot be attributed directly to the standardization since they would be made independently of it. Hence we shall have four types of investment to be accounted for as standardization costs. These are as follows:

(A) Widen the gauge where a 1.60 m gauge substructure already exists on a 1.00 m gauge line.

(B) Widen the gauge where there is only the 1.00 m gauge substructure.

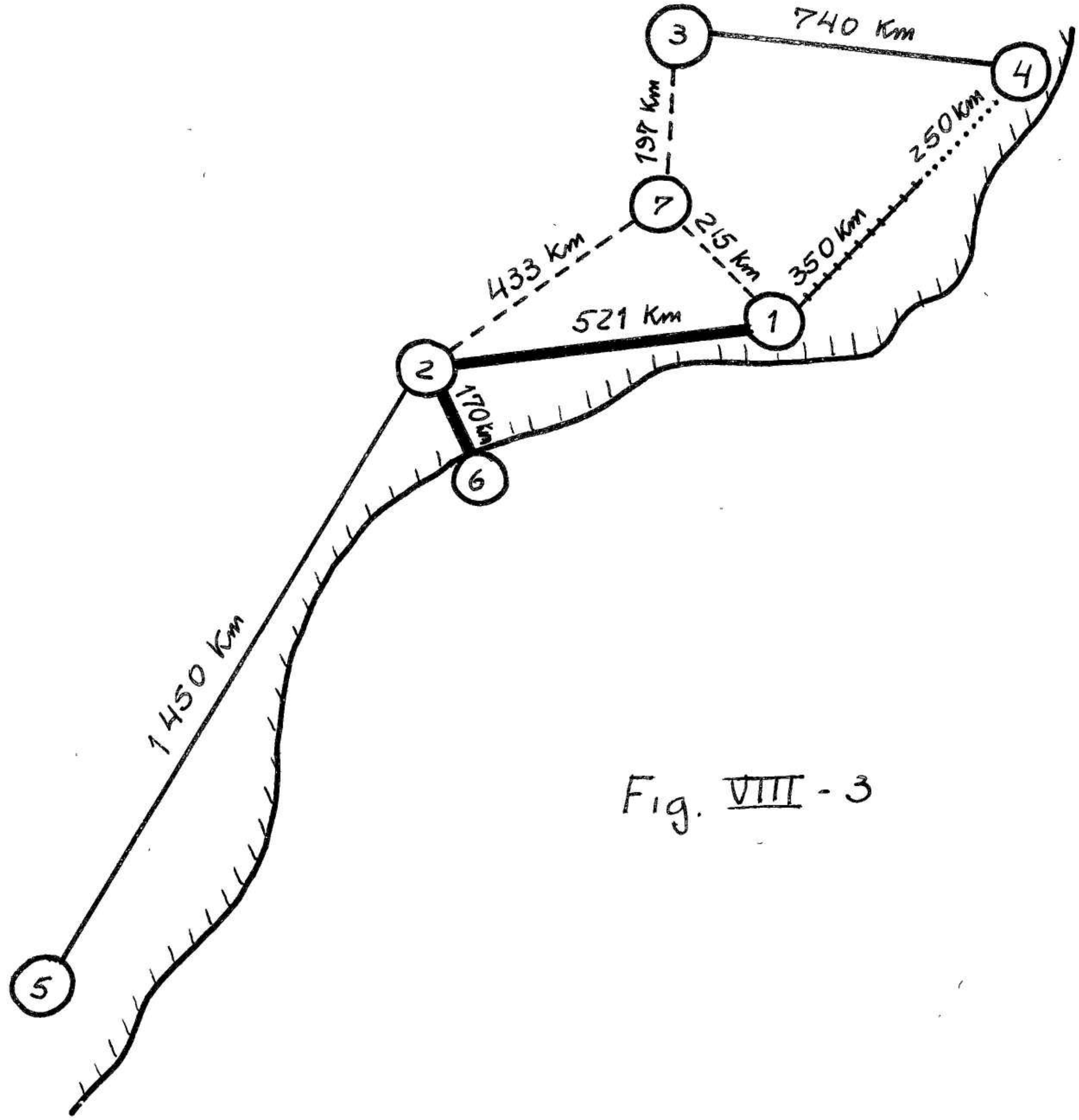


Fig. VIII - 3

Existing 1.60m gauge Line
Existing 1.00m gauge Line to be widened to 1.60m
Existing 1.00m gauge Line to be widened and upgraded
Projected 1.60m gauge Line
Projected 1.00m gauge Line to be widened to 1.60m

Line	Km	Type of Investment	Type of Terrain	Cost (Cr $) (1974)
3-4	640	A	*	236,541,000
	100	B	Flat	67,391,000
1-4	150	D	Flat	50,998,000
	100	D	Rolling	132,937,000
	260	B	Flat	173,189,000
	40	B	Mountainous	135,214,000
	10	C	Rolling	17,558,000
	40	B	Rolling	66,220,000
2-5	270	B	Flat	179,850,000
	80	B	Rolling	132,434,000
	1100	A	*	408,220,000

Table VIII-3

*Type A investment does not require terrain classification because only track structure costs are included and they do not depend on the type of terrain

(C) Widen the gauge and upgrade the line.

(D) Change the design project from 1.00 m gauge to 1.60 m gauge.

Fitting the given classification we have the following lines:

(1) Belo Horizonte (3) to Vitoria (4) with 640 km of type A and 100 km of type B investments.

(2) Rio de Janeiro (1) to Vitoria (4) with 340 km of type B, 10 km of type C, and 250 km of type D investments.

(3) Sao Paulo (2) to Porto Alegre (5) with 1,100 km of type A and 350 km of type B investments.

The costs of these investments were estimated using the cost model described in Appendix 1. The model called for the definition of the type of terrain over which the lines would pass. This was easily obtained through the description of existing lines, providing, therefore, reasonably accurate results which are given in Table VIII-3. From this table we obtain the total cost imputed to standardization, which is Cr $1,600,552,000, or approximately US $200 million.

Equipment costs are not included because they will be minimal for 3 reasons:

(1) 1.00 m gauge can be used on the remaining 1.00 m gauge lines of the network,

(2) standardization will increase equipment utilization (see Appendix 2),

(3) Acquisition of new 1.60 m gauge equipment is due primarily to traffic expansion, not standardization.

Yard costs are also not included for two reasons:

(1) they are very difficult to measure accurately

(2) it was difficult to distinguish between costs due to standardization and costs due to modernization and rehabilitation of yards and terminals recommended in the previous sections to improve railroad service.

We believe, however, that this omission will not have much weight on the final result since on the benefit side the reduction of such costs as direct freight interchange costs and operating costs, which would easily offset yard costs, will also be omitted.

Benefits of Standardization

The standardization of a basic network in the southeast would provide several benefits that were amply discussed in the previous sections. Not all, however, are easily measurable. For example, the increase in reliability, the better car utilization, the decrease in loss and damage due to less additional handling at gauge break points, and other ensuing benefits are difficult to quantify and translate into money figures a priori. Only two measures of cost savings seem appropriate in this case. First are the costs of transferring freight between gauges and second are the savings that could be obtained through piggy-back and truck-on-train (see Chapter V, Section A) operations on run-through trains made possible by the standardization on a wider gauge.

Yet there are no figures available on the cost of transferring freight between lines of different gauges. Therefore, the only benefits that will be directly quantified here will be the result of truck-on-train and piggy-back operations. Hopefully, if this somewhat limited approach proves feasible, greater confidence can be attributed to anticipated savings through standardization because several other benefits which were not counted will ensue.

To measure the benefits due to truck-on-train and piggy-back operations, we have to estimate their flow and relative costs.

To estimate the demand for truck-on-train and piggy-back transportation several commodities with rail potential but presently being carried in part by trucks were considered.[16] These included:

1,311,000 tons of cement

2,826,000 tons of oil products

3,646,000 tons of steel products

61,000 tons of fertilizers

58,000 tons of limestone

634,000 tons of other commodities.

The rationale for this study would then be that the standardized network would attract these commodities to the railroads. Since, however, it cannot be realistically expected that the truckers, with all their entrepreneurship and rate flexibility would easily abandon more than 8 billion tons of freight

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[16] See [5].

to the railroads, only a compromise solution can be expected, that is, the combination of truck and rail transportation provided by truck-on-train and piggy-back operations.

Following a close examination of each commodity relative to quantities and origin or destination, a origin-destination matrix (see Table VIII-4) was constructed fitting our purposes and definitions.

	1	2	3	4	5	6	7
1		1083.6	793.8	975.8	809.5	—	23.8
2			677.5	40.0	901.0	702.0	24.0
3				903.0	699.0	60.0	278.5
4					—	—	294.8
5						—	271.0
6							—
7							

Table VIII-4

In this figure, values are in thousand tons. Note that the matrix is symmetrical.

Using the freight traffic growth rates, estimated in [6], that is, 8% until 1985 when the National Steel Plan will be fully implemented and 6% from then on, we obtain the future demands for truck-on-train and piggy-back transportation. The split between the two modes was calculated to favor truck-on-train operations in the first three years of operations by 40%, 20% and 10% respectively due to the more stringent adaptation requirements of piggy-back transportation as opposed to truck-on-train operations, which require only a crane to hoist the truck on the train with the drivers riding on the train. To obtain the cost savings, we first have to estimate the costs for each mode.

From data for truck, truck-on-train, and piggy-back transportation costs available for 15 origin-destination pairs[17] we were able to fit 3 regression curves relating cost per ton (Y) with distance (X). They are:

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[17] See [6].

(a) Truck

$$Y = 11.50760 + .11674X \qquad R^2 = 0.99$$

(b) Truck-on-Train

$$Y = 6.24305 + 0.07827X \qquad R^2 = 0.99$$

(c) Piggy-Back

$$Y = 34.07863 + 0.02721X \qquad R^2 = 0.92$$

With the cost equations obtained from the regressions, we can now build a cost matrix for each of the three modes.

Once the flows, the traffic growth, and the transport costs have been obtained, the costs savings can easily be calculated.

For a period of 15 years, which is approximately the half life of the track structure, from 1975 to 1990, with the National Steel Plan fully implemented, the cost savings are given in Table VIII-8. An estimated time of 2 years was given for the complete implementation of the proposed standardized network so that cost savings only began to be computed from 1977 on.

	1	2	3	4	5	6	7
1		72	60	82	242	92	37
2			85	142	181	31	62
3				98	142	105	35
4					312	162	121
5						201	231
6							82
7							

Table VIII-5

Truck Costs

*Cost per ton (Cr $) (1974)

	1	2	3	4	5	6	7
1		47	38	53	161	60	23
2			56	94	120	20	40
3				64	94	69	22
4					207	107	80
5						133	154
6							53
7							

Table VIII-6

Truck-on-Train Costs

	1	2	3	4	5	6	7
1		48	45	50	88	53	40
2			51	65	74	39	46
3				54	65	56	39
4					104	69	60
5						78	85
6							51
7							

Table VIII-7

Piggy-Back Costs

Year	TRUCK		TRUCK-ON-TRAIN		PIGGY-BACK		Cost Savings
	10^3 tons	10^6 Cr $	10^3 tons	10^6 Cr $	10^3 tons	10^6 Cr $	
1975	—	—	—	—	—	—	—
1976	—	—	—	—	—	—	—
1977	5356.1	954.1	5090.5	564.8	565.6	49.0	340.3
1978	6108.6	1030.4	4276.0	474.5	1832.6	158.8	397.1
1979	6597.3	1112.9	3958.4	439.2	2638.9	228.7	445.0
1980	7125.1	1201.9	3562.6	395.3	3562.6	308.8	497.8
1981	7695.1	1298.0	3847.6	426.9	3847.6	333.5	537.6
1982	8310.7	1401.9	4155.4	461.0	4155.4	360.1	580.7
1983	8975.5	1514.1	4487.8	498.0	4487.8	388.9	627.2
1984	9693.6	1635.2	4846.8	537.8	4846.8	420.1	677.3
1985	10469.0	1766.0	5234.5	580.8	5234.5	453.7	731.5
1986	11097.1	1872.0	5548.6	615.6	5548.6	480.9	775.5
1987	11763.0	1984.3	5881.5	652.6	5881.5	509.8	821.9
1988	12468.7	2103.3	6234.4	691.7	6234.4	540.4	871.2
1989	13216.9	2229.5	6608.4	733.2	6608.4	572.8	923.5
1990	14009.9	2363.3	7004.9	777.2	7004.9	607.2	978.9

Table VIII-8

Conclusion

Computing the present value (1975) of the cost savings from 1975 to 1990 at the two discount rates recommended by the World Bank — 15% and 18% — we obtain the values shown in Table VIII-9. Comparing the present values of the total costs savings at the two discount rates, we see both are significantly larger than the estimated total cost of standardization as reported

15%: Cr $2,762,000,000 > Cr $1,600,552,000

18%: Cr $2,286,500,000 > Cr $1,600,552,000

Even though the present analysis might be subject to several restrictions, either due to its own limits on data accuracy and prediction power or to limits of cost-benefit analysis in general, it provides a powerful insight into the gauge problem. Experience may prove that the above numbers are incorrect, however, due to the significant difference between estimated costs and benefits, we can safely assert the feasibility of the proposed standardized network. Furthermore, in this case, those benefits which could not be properly measured will no doubt play

Year	Present Value (10^6 Cr $)	
	15%	18%
1975	—	—
1976	—	—
1977	257.3	244.4
1978	261.1	241.7
1979	254.4	229.5
1980	247.5	217.6
1981	232.4	199.1
1982	218.3	182.3
1983	205.0	166.9
1984	192.5	152.7
1985	180.8	139.8
1986	166.7	125.6
1987	153.6	112.8
1988	141.6	101.3
1989	130.5	91.0
1990	120.3	81.8
Total	2762.0	2286.5

Table VIII-9

a major role, strengthening the basic finding, namely, the economic feasibility of the basic standardized railroad network for Brazil as proposed herein.

BIBLIOGRAPHY[1]

1. Ministry of Transportation. "Transport Statistical Yearbook." G.E.I.P.O.T. Rio de Janeiro, 1971 and 1972.
2. ________________. "Railway Development Program, 1975/1979." Brasilia, 1975.
3. ________________. "Brazilian Transport Survey." Rio de Janeiro, 1967.
4. ________________. "Brazilian Railway Specifications." Rio de Janeiro, 1969.
5. ________________. "Study of the Railway Network in the States of Sao Paulo, Rio de Janeiro, and Minas Gerais. DNEF 02/71." TRANSCON. Rio de Janeiro, 1972.

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[1]This bibliography is complemented by the author's experience and personal contacts at the time of his work at the Brazilian Transport Planning Agency (GEIPOT) from 1972 to 1974.

6. ________________. "Final Report of the Railroad Group." GEIPOT. Rio de Janeiro, 1974.

7. Federal Railway Network. RFFSA. "Statistical Yearbook." Rio de Janeiro, 1971, 1972, 1973, and 1974.

8. ________________. "Railway System." Rio de Janeiro, 1974.

9. ________________. "Legislation and Regulation." Rio de Janeiro, 1964.

10. ________________. "Annual Report." Rio de Janeiro, 1974.

11. ________________. "Annual Report for the Center Regional System." Rio de Janeiro, 1974.

12. ________________. "Statistics for the South Central System." Porto Alegre, 1974.

13. National Department of Railroads. DNEF. "Brazilian Railway Statistics." Rio de Janeiro, 1972.

14. Ministry of Planning and Coordination. "Brazilian Statistical Yearbook." IBGE. Rio de Janeiro, 1960 to 1974.

15. Association of Latin American Railways. ALAF. "Latin American Railway Statistical Yearbook." Buenos Aires, 1974.

16. Pan American Railroad Association. "Bulletin." Buenos Aires, 1967 and 1970.

17. International Bank for Reconstruction and Development. "Railway Traffic Costing." Washington, D.C., 1974.

18. International Railway Association. U.I.C.F. "Bulletin." Bern, 1963.

19. T. Matsudaira. "The Tokyo - Tokaido Line." Japanese Railway and Engineering. Vol. 17, No. 2. Tokyo. June, 1966.

20. S. Joy. "The Train that Ran Away." Ian Allan, Ltd. London, 1973.

21. W. Hay. "Railroad Engineering." John Wiley and Sons. New York, 1969.

22. S. Guins. "Freight Car Impact." The American Society of Mechanical Engineers. New York, 1971.

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

24. "Railway Track and Structures Encyclopedia." Simmons-Boardman Pub. Corp., New York. 1955.

25. C. Martland. "Methodologies for Developing and Evaluating More Effective Railroad Networks." Studies in Railroad Operations and Economies, Vol. 18. M.I.T., 1975.

26. "Screening Models." Progress Report on the Study of Methodologies for Developing and Evaluating Effective Rail Networks. M.I.T., October 1974.

27. J. Sloss, T. Humphrey, and F. Krutter. "An Analysis and Evaluation of Past Experience in Rationalizing Railroad Networks." Studies in Railroad Operations and Economics. Vol. 16. M.I.T., February 1975.

28. M. Manheim. "Fundamentals of Transportation Systems Analysis." M.I.T., 1974.

29. G. Coimbra. "History of Brazilian Transports." Ministry of Transportation, Rio de Janeiro, 1974.

30. Jane World Railways. McGraw-Hill, New York, 1974.

31. J. Howland. "The Cost of Transport Regulations in Brazil." Unpublished paper. State University of New York, New York, 1974.

32. A. Vilhena. "Heavy Rail Transport at Medium Speeds." TRANSCON. Rio de Janeiro, 1974.

33. Association of American Railroads. "Operating and Traffic Statistics." Washington, D.C., 1973.

34. J. Sloss, F. Krutter, and L. C. G. de Souza. "Intercity Freight Transportation in Developing Countries." M.I.T., 1975.

APPENDIX I

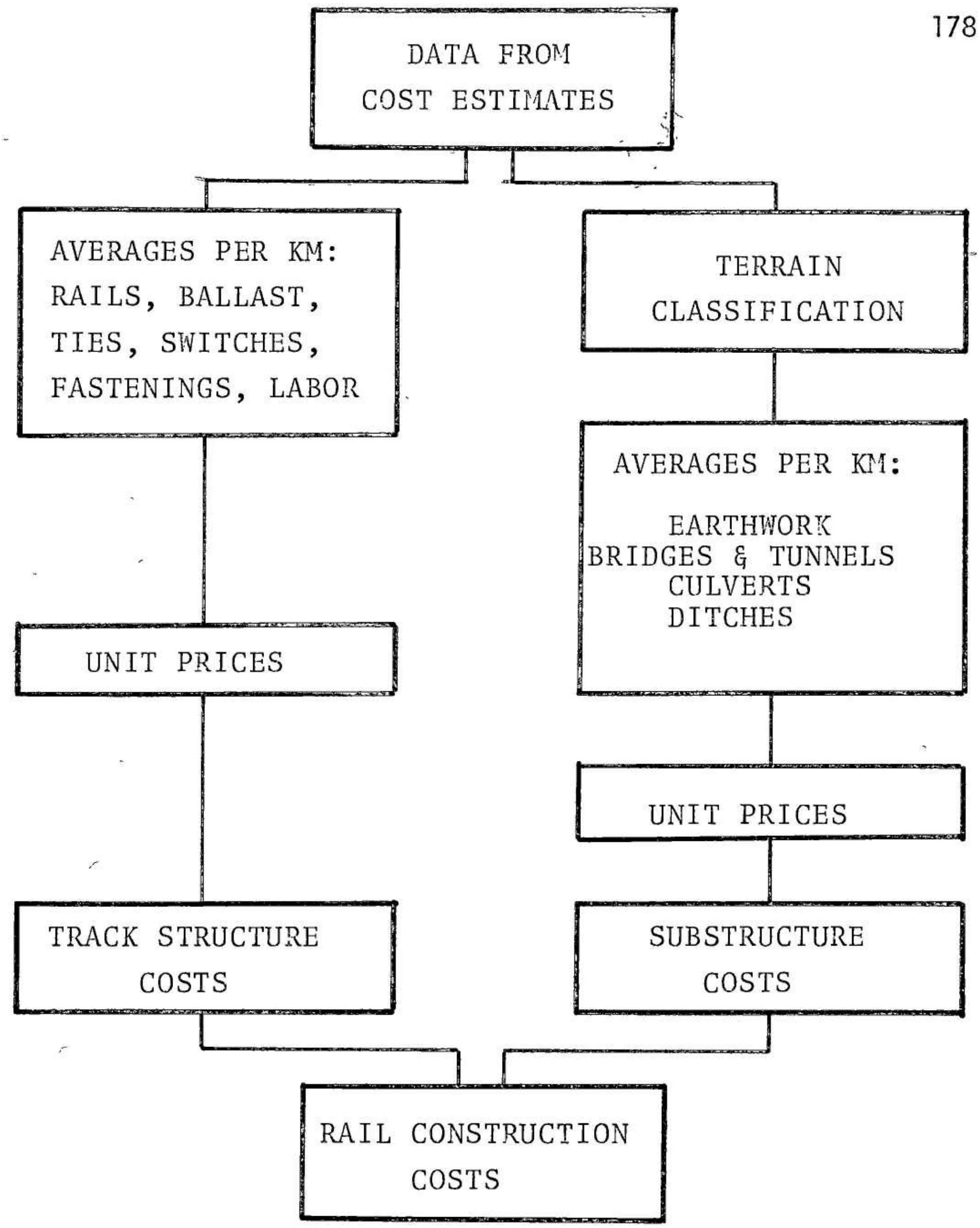
STANDARDIZATION COST MODEL

This appendix presents a simple model that can be used to estimate the construction cost due to change from a 1.00 m gauge line to a 1.60 m gauge in Brazil. This model is basically a construction cost model such as depicted in Figure APP1, adapted to estimate the cost of changing gauges.

Given the total mileage of the route in kilometers, the type of terrain over which it passes, and the type of investment required, it is possible to obtain the construction costs desired.

The four possible types of investment described in Chapter VIII are:

(A) Widen the gauge where a 1.60 m gauge substructure already exists



RAIL CONSTRUCTION COST MODEL

Figure APP1

(B) Widen the gauge where there is only the 1.00 m gauge substructure

(C) Widen the gauge and upgrade the route

(D) Change the design project from the 1.00 m gauge to the 1.60 m gauge.

The above distinction is important because significant differences exist: For example, investment type A only occurs in track structure costs, whereas investment type B also requires substructure changes and investment type C an additional upgrading of the route. As to investment type D, it is basically similar to investment type B with the difference that it does not subtract the residual value of the existing tracks from the total cost.

At a crude level, the following type of model might be used for each type of terrain:

$$\text{COST} = \text{KMS}\ (\text{EW}p_i + \text{BT}p_2 + \text{CV}p_3 + \text{DT}p_4 + \text{K(UP)}p_1) + \text{KMS}\ (\text{SW} - \text{L(SN)} - \text{M(RES)})$$

where COST = total cost of standardization

KMS = kilometers of route

p_i = unit prices

EW = average earthwork volume per km

BT = average length of bridges and tunnels per km.

CV = average length of culverts per km.

DT = average length of ditches per km.

UP = average earthwork volume per km due to line upgrading

SW = average track structure costs per km for the 1.60 m gauge

SN = average track structure costs per km for the 1.00 m gauge

RES = average residual value of track per km.

K,L,M = constants assuming values of 1 or 0, depending on the investment type

The first expression constitutes the substructure costs including earth moving, bridges, tunnels, culverts, and ditches. The second expression represents the track structure costs and includes such items as heavy weight rails, ballast, wooden ties, track fastenings, switches, and labor. For the residual value of tracks, an average accumulated depreciation of 50% was considered.

A more rigorous approach would include traffic density as a variable in influencing, for instance, the rail weight. In the present case, however, for simplicity sake we assume density to be high, requiring heavy weight rails throughout.

The model was calibrated from available cost estimates of the following lines (as of August 1974).[1]

(1)	Carajas - Sao Luiz	930 km
(2)	General Luz - Rio Grande	340 km
(3)	Roca Salles - Passo Fundo	160 km
(4)	Casiovel - Foz do Iguiacu	148 km
(5)	Apucarana - Guaira	361 km
(6)	Apucarana - Ourinhos	268 km
(7)	Costa Lacerda - Brasilia	1306 km
(8)	Belo Horizonte - Salvador	1640 km
(9)	Campinas - Sorocaba	91 km
(10)	Campinas - Carapicuiba	79 km
(11)	Sorocaba - Presidente Epitacio	738 km
(12)	Campinas - Giorandera	771 km
(13)	Apucarana - Paranagua	178 km
(14)	Casiavel - Engº Bley	475 km

[1]See [6].

In each case, available figures included the number of kilometers of route, the type of terrain, the type of rail, the type of ties, the earthwork volumes, the length of bridges, tunnels, culverts, and ditches.

The following equations were obtained:

Flat Terrain:

$$\text{COST} = \text{KMS}\ (2874p_1 + 10p_2 + 50p_3 + 2000p_4 + 10324Kp_1) + \text{KMS}\ (654437 - 609457L - 283328M)$$

Rolling Terrain:

$$\text{COST} = \text{KMS}\ (8550p_1 + 60p_2 + 70p_3 + 3000p_4 + 49915Kp_1) + \text{KMS}\ (654437 - 609457L - 283328M)$$

Mountainous Terrain:

$$\text{COST} = \text{KMS}\ (200376p_1 + 150p_2 + 100p_3 + 4000p_4) + \text{KMS}\ (654437 - 609457L - 283328M)$$

In the mountainous terrain no upgrading variable was included since the larger curvature of the wider gauge would require practically the construction of a brand new line with more tunnels and bridges.

The unit prices shown below are as of August 1974.[2]

[2] Ibid.

$p_1 = 8.70$ Cr \$ / m^3

$p_2 = 18{,}000.00$ Cr \$ / m

$p_3 = 1000.00$ Cr \$ / m

$p_4 = 20.00$ Cr \$ / m

A key issue for the good performance of the model is, of course, a clear definition of the type of terrain over which the line must pass. However, in the cases where the lines already exist, the description of existing lines provides quite accurate information. In fact, the model was tested for the Campinas - Carapicuiba and the Apucarana - Ourinhos lines with differences of only 7% and 11% from the actual estimates (see printout).

This type of model may not be as accurate for new lines with different locations. Nevertheless, it serves the present purpose and provides quick estimates of costs of standardizing rail lines in Brazil.

```
1    '     STANDARDIZATION COST MODEL FOR BRAZIL
2    '
3    '     Types of investment considered:
4    '
5    '     1 - Wider gauge with substructure ready
6    '     2 - Wider gauge without substructure
7    '     3 - Widen gauge and upgrade tracks
8    '     4 - Alter gauge in the design project
9    '
10   all=0
15   i=0
20   p1=8.70
25   p2=18000.00
30   p3=1000.00
40   p4=20.00
60   i=i + 1
70   k=0
100  input km(i), terr(i), invst(i)
105  if km(i)=0 then 250
110  if invst(i)=3 then k=1
115  if terr(i)=2 then 150
120  if terr(i)=3 then 170
130  icost(i)=km(i)*(2874*p1+10*p2+50*p3+2000*p4+10324*p1*k)
140  goto 180
150  icost(i)=km(i)*(8550*p1+60*p2+70*p3+3000*p4+49915*p1*k)
160  goto 180
170  icost(i)=km(i)*(200376*p1 + 150*p2 + 100*p3 + 4000*p4)
180  scost(i)=371109*km(i)
190 if invst(i) < 4 then 210
200  scost(i)=44980*km(i)
210  if invst(i)=1 then icost(i)=0
220  total(i)=scost(i) + icost(i)
225  all=total(i) + all
230  print "SECTION",i,"COST =",total(i)
240  goto 60
250  print "TOTAL COST DUE TO STANDARDIZATION =",all
260  stop
```

```
1    '    DATA FOR THE CAMPINAS-CARAPICUIBA LINE (90 km)

goto 1
?79 3 1

SECTION         1              COST =           29317611
?
 11 2 1

SECTION         2              COST =           4082199
?
 0 0 0

TOTAL COST DUE TO STANDARDIZATION =             33399810
 (at 260) Stop.

2    '    DATA FOR THE APUCARANA-OURINHOS LINE (268 km)

goto 1
?199 2 2

SECTION         1              COST =           3.29443 E+8
?
 69 2 3

SECTION         2              COST =           1.44193 E+8
?
 0 0 0

TOTAL COST DUE TO STANDARDIZATION =             4.73636 E+8
 (at 260) Stop.
```

APPENDIX II

SCREENING MODELS[1]

This appendix illustrates the usefulness of screening models in helping railroad managers evaluate rationalization alternatives.

Two screening models are used as examples:

(1) Power requirements model

(2) Freight car requirements model.

They are tested against 1973 data for the Southeast railroad network to evaluate alternatives connected with the possible standardization of that part of the Brazilian network to 1.60 m gauge, as well as other rationalization alternatives offered.

---

[1]The screening models illustrated in this appendix are basically similar to those developed in [26].

1. Power Requirements Model

As a first approximation, the number of locomotive units required by a railroad system is given by:

$$L = \frac{NV}{8760U_{\ell}SM}$$

where L = the required number of locomotives

N = average number of locomotives per train

V = annual freight car-km.

8760 = number of hours in a year

U_{ℓ} = measure of locomotive utilization expressed as the fraction of time that the locomotives are in train service

S = average train speed

M = average train length

These parameters can be individually determined in the following way:

$$N = \text{locomotive-km/train-km}$$

$$S = \text{train-km/train-hr}$$

$$U_{\ell} = \text{locomotive-km/serviceable locomotive-day/}24S$$

$$M = \text{car-km/train/km}$$

Using the averages for the Sao Paulo railroads and the Center and South-Center system of the Federal System[2] we have the following results:

$$N = 2.3$$

$$V = 700{,}096{,}000$$

$$U_\ell = 0.47$$

$$S = 17.3$$

$$M = 23.9$$

Thus

estimated L = 945

actual L = 905.

Assuming that one alternative consists in increasing the average speed from 17.3 km/hr to 25 km/hr which is lower than the Eastern U.S. System[3] by such measures as upgrading and widening the tracks, the model estimates L = 654, i.e., an economy of 291 locomotives.

Another rationalization alternative could be to revise policies for assigning locomotives to trains which would increase locomotive utilization from 0.47 to 0.60. This would reduce the number of locomotives required by 200.

---

[2] See [15].
[3] See [26].

One of the problems of the Brazilian railroads is the low horsepower of the locomotives. Assuming that the average horsepower is increased, allowing for the average train length to increase from 23.9 cars to 35 cars, which is the average for Mexico[4] the number of locomotives required would be only 645 as compared to 945, i.e., 300 less.

2. Freight Car Requirements Model

For a quick estimate of freight car requirement, railroad planners can use the following model:

$$F = \frac{T}{U_f KPM}$$

where F = number of freight cars required

T = net ton-km per day

U_f = car capacity utilization

(= ton-km/loaded car-km/K)

K = average car capacity

P = ratio of loaded car-km to total car-km

M = car-km per serviceable car-day

[4]See [15].

Using the model on the network previously defined would yield the following results:

$$T = 36{,}209{,}000$$

$$K = 37.0$$

$$U_f = 0.74$$

$$M = .70$$

$$P = 53.1$$

Thus

estimated F = 35,646

actual F = 34,751.

Assuming now that the network was standardized, thereby eliminating gauge breakpoints and facilitating longer average hauls, the average trip per day of a freight car would no doubt increase. If this increase could reach 70 percent of the present Mexican levels, this would mean that only 26,989 of the present-day cars would be required, i.e., 8657 less than actually owned.

If capacity utilization could be increased from 0.74 to 0.80, as compared to Mexico's overall average of 0.875,[5] only 32,972 freight cars would be required, signifying an economy of 2,674 freight cars.

---

[5]Ibid.

As we have seen, screening models provides a quick and powerful evaluation of several rationalization alternatives considered. It tells us, for instance, that if standardization can improve car utilization, since the same freight car can be used throughout the network, savings of up to 25 percent of the total number of freight cars can be reasonably expected, and this is very important when the total costs of the program are being estimated. Thus, the railroad managers can select several alternatives through screening models for further and more detailed study.