SOCIO- SPATIAL SEGREGATION AND THE LEVEL OF SERVICE OF PUBLIC TRANSPORT IN RIO DE JANEIRO, BRAZIL.

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by

Antônio Paulo Richard Câmara

Bartlett School of Architecture and Planning

University College London

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To all those dependent on Public Transport and to all bus drivers and conductors in Rio de Janeiro and elsewhere.

ABSTRACT

The Brazilian urbanization model has been consolidated in such a way that most cities, and especially the Metropolitan regions, concentrate in their cores not only wealth but also services and the labour market . This results in very high densities. Contrary to this, peripheral areas concentrate poverty and lack of services. This results in lower densities. However these areas are the ones that have been presenting the highest growth rates.

What effect does this land use pattern have in the transportation field? What kind of public investments have been made to cope with this spatial configuration of Brazilian urban areas? Is there any relationship between the distribution of the population and the quality of public services, amongst them transport?

The aim of this research is to evaluate the public transport system in Rio de Janeiro, taking into account not only the segregation of activities such as housing and labour market but also the stratification of the population in economic and social terms to establish what level of service is provided for people in different income groups.

Rio de Janeiro is taken as the best Brazilian example as public investments and market have not only determined where and how one would live, but have also shaped the city in such a way, that good access to facilities has been the privilege of a minority.

Transport, as one of the most important public services, will be used as a tool to test the hypothesis that public services are unevenly distributed

among different areas in the city and consequently among different population strata.

The bus mode was selected for further investigation, as being the main mode of public transport in Rio de Janeiro. A survey was carried out among users within the system in 15 selected routes. The survey findings supported the hypothesis raised initially, and significant differences in attributes such as waiting, walking and in-vehicle times and also travel costs were observed between the core and peripheral householders.

One of the greatest contributions of this research was regarding to the bus drivers working conditions. The quality of the services provided, independently from the spatial variable seems to be affected by the very poor working conditions of the crews. Although improvements in the transport system are necessary, they are not sufficient to solve the problem of commuters, unless significant changes also take place in the working conditions of the drivers.

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CHAPTER I- INTRODUCTION

I.1- INTRODUCTION.

Public transport in Brazil is inadequate and it does not meet passengers' needs, especially the needs of those who are dependent upon the public system. Moreover, the level of service provided differs significantly between wealthier and poorer areas and this is reflected in the investments within the sector. Fares are high for most of the population and most of the time the network does not cover all the main destinations which leads to the need for interchanges, especially for those living in peripheral areas. There is no comprehensive integrated fare system among different modes or even within one single mode, and those who have to interchange are forced to pay even higher costs.

The aim of this research is to evaluate the quality of public transport in the city of Rio de Janeiro, taking into account the fact that the population is spatially distributed in accordance to their income, and to establish to what extent the quality of the services is differentiated between wealthier and poorer areas.

Two main hypothesis are raised. The first one is that income plays a decisive role in determining where the population live and the second one is that transport services are unequally distributed among different areas in the city.

The Brazilian urbanization model has been consolidated in a way that most cities and especially metropolitan areas, concentrate in their cores the wealth, higher income groups, services and most of the job market, higher density, while peripheral areas, in contrast, concentrate poverty, lack of services or poorer services, and presents the highest population growth rates, yielding a degree of dependence already established between the periphery and the core.

This land use pattern generates daily a great many trips towards the core in the morning and towards the periphery in the afternoon. The transport system seems incapable of providing a reliable and comfortable service especially within poorer areas or between poorer areas and the core, mainly because of this concentration of demand in time and space; the classical peak problem.

Rio de Janeiro is certainly one of the best Brazilian examples where the capital has not only determined where and how one would live, but also shaped the city in such a way that access to amenities is a privilege of a minority.

If public services provision is analysed this fact becomes more evident. Transport, as one of the most important public services, is analysed in this research. Rio de Janeiro generates approximately five million trips daily by public transport, of which 80% are made by bus. The two other modes are the underground and the railway system. Each of these modes have different captive demands, socially and economically speaking.

It is also interesting to point out the importance and the role transport has played and still plays in Rio de Janeiro urbanization process and in the consolidation process of segregating the population.

The railway system and tramway systems were both implemented during the last century and somehow divided the city into two completely different areas. The train developed the city towards the western and northern zones and suburbs (the poor city) while the tramway developed it towards the southern zone and the sea side (the wealthy city). This pattern has been reinforced over the years and even recently Rio de Janeiro has experienced higher investments in its transport system within the core to the detriment of the periphery, with the option of constructing an underground system mainly concentrated within the core.

Trams were the principal mode of transport until the 1950s, although the first buses appeared in the city already during the 1930s and 1940s bringing about many changes in the type of services in operation (Fuigueroa, O. 1988).

In Latin America as a whole, the tramway suited quite well the era of urban consolidation of the big cities' central areas, while the bus later assumed a dominant role with the expansion of the urban fabric towards the suburbs during periods of fast population growth.This expansion of the bus system as the main public mode of transportation is without doubt, due to the low investment involved (mainly only the vehicles), and no investment concerning infrastructure or its maintenance (Figueroa, O. op. cit.).

The bus system serves the city of Rio de Janeiro more extensively but services are not equally distributed, and peripheral users are more likely to be subjected to higher headway and longer waits, longer distances to travel and consequently longer journey times, overcrowding, higher fares, more interchanges and overall a poorer service. This research will focus on the bus system mainly because of its importance in terms of daily captive demand and also because it operates a more extensive network in the city.

The purpose of this work is to call for attention from the the Government and all those involved in the provision of public transport to be aware of the quality of the services provided and to suggest what kind of measures could be taken in order to provide a more equal service among different areas in the city, independently from the income of the population and finally that transport would fulfil the needs of lower income and peripheral householders more satisfactorily.

It must be mentioned that the thesis is partly based on data from secondary sources. Any inconsistency that might be observed may be due to these different sources.

The thesis is structured into eight Chapters, including this introductory one. Chapter II gives evidence of the Brazilian urbanization process, emphasizing the core-periphery model. Empirical data, from the Rio de Janeiro case study, will support this argument especially when income distribution, car ownership and educational background are considered.

Chapter III presents the transport system in Rio de Janeiro, giving a historical background and the importance of the public transport in the city urbanization and segregating processes. Further, each of the current public modes of transportation is presented, and a detailed picture of the network distribution, demand and fare levels are highlighted, as well as the availability of private transport.

Chapter IV evaluates the transport system focusing on the bus mode. Some performance measurements are presented and discussed and the operators performance is analysed from two different perspectives; an economic one and a spatial one.

Chapter V, Social Analysis, introduces some of the classical attributes for assessing a transport system efficiency such as accessibility, reliability, comfort and convenience, and safety. Afterwards the survey methodology and the further findings are presented. Here the level of service is tested for the different areas in concern, and the attributes presented previously are checked according to a spatial dimension.

Chapter VI, interprets some of the figures and results from the previous Chapter, and go into further detail comparing variations between the different areas under analyses. In this chapter the differences in the quality and quantity of services provided are more clearly identified.

Chapter VII presents a selection of criteria and according to this the bus system is selected as the mode in which most measures to improve the transport system should take place, mainly because the system caters for a more representative demand in the municipality context, it is the most flexible one and the one which requires the least investment if compared to the other modes of public transport. However the railway and the underground systems should not be neglected and some improvements in the former and the completion of the latter were highly recommended as well. In the last Chapter, final conclusions are presented and guidelines for further research are suggested.

CHAPTER II- THE STUDY AREA

II-1. THE BRAZILIAN CONTEXT.

The Federal Republic of Brazil covers more than eight million square kilometres, which represents nearly half of the South American continent.

Since 1940, the economy and society in Brazil have experienced significant changes. In four decades population has tripled in absolute terms and the percentage of rural and urban population has shifted from 69% and 31% in 1940, to 33% and 67% in 1980 respectively. The relative increase in the urban population in the same period was 621%, while in the rural one was only 141%. It is interesting to note that in absolute numbers the rural population starts to decline after 1970. Table I shows figures for the population growth in Brazil for the period 1940-1980.

TABLE I

URBAN AND RURAL POPULATION IN BRAZIL- 1940-1980 (x 1.000)

YEAR	URBAN	%	RURAL	%	TOTAL
1940	12,800	31	28,356	69	41,236
1950	18,783	36	33,162	64	51,945
1960	32,805	45	38,988	55	71,793
1970	52,905	56	41,604	44	94,509
1980	80,000	67	40,000	33	120,000

SOURCE: FIBGE, Anuário Estatístico do Brasil, 1981, Rio de Janeiro.

The distribution of the population is quite uneven among the different regions within the country. Most of the urban centres and nine metropolitan regions are located on the Atlantic coast. The South and Southeast regions concentrated (in 1970), 60% of the country's population on only 18% of the land, while the Northeast region concentrated 33% of the population in the same amount of land. So 93% of the population was concentrated in only 36% of the territory. The other 7% of the population is spread within nearly two thirds of country in the North and Centre-West regions.

Among many other repercussions of this rapid growth in population and its concentration in some metropolitan areas, the impact on the provision of public services including urban transport can be noticed.

To give more detail in respect to the distribution of the population; In 1980 approximately 30% of the Brazilian population lived in one of the nine metropolitan areas. São Paulo and Rio de Janeiro metropolitan regions concentrated 70% of this total. Table II shows the population distribution in the nine Brazilian Metropolitan regions, as well the number of vehicular trips generated daily by both public and private transport systems in 1978, as well the daily trip ratio per person. Map I shows the five regions in Brazil and the respective Metropolitan Regions.

While evidence indicates a degree of economic development within these metropolitan regions, especially São Paulo and Rio de Janeiro, it does not necessarily reflect changes in the quality of life of the population. On the contrary, it appears that in Brazil economic growth and living standards are to be frequently interconnected. Living conditions are dependent on a series of factors, of which working conditions are possibly the most important. Some research into these conditions of urban expansion, including services, infrastructure, social relationships and consumption levels suggested that they are all closely related to economic growth (Kovarick,L, 1987).

TABLE II

BRAZILIAN METROPOLITAN REGIONS POPULATION IN 1980, TRIPS GENERATED DAILY BY PUBLIC AND PRIVATE TRANSPORT AND DAILY TRIP RATIO (1978).

Metropolitan Region	Population	Daily Vehicular Trips (x 1,000)	Daily Trip Ratio
I- Southeast Region			
São Paulo	12,588	16,419	1.30
Rio de Janeiro	**9,019**	**10,059**	**1.11**
Belo Horizonte	2,542	2,360	0.92
II- Northeast Region			
Recife	2,348	2,149	0.91
Salvador	1,772	1,962	1.10
Fortaleza	1,582	1,085	0.68
III- South Region			
Porto Alegre	2,232	2,801	1.25
Curitiba	1,442	1,740	1.20
IV- North Region			
Belém	1,000	1,170	1.17
TOTAL	34,525	39,745	1.15

SOURCE: GEIPOT-EBTU, Brasília, 1981.

MAP I- THE FEDERAL REPUBLIC OF BRAZIL

If the daily rates of trips are taken into account, on average, 47% of the trips have work as their main purpose. Modal split is as follows: 28% of the trips are made by private car, 62% by bus and 10% by other modes of public transport. There is no data available concerning walking trips.

In the specific case of Rio de Janeiro Metropolitan Region, figures are respectively, 47.6% for working purposes and modal split, respectively, 21%, 68% and 11%, by private car, bus and other modes (PITMETRO, 1977).

The national economic core remains in the South and Southeast regions. In 1970 both regions were responsible for more than two thirds of the agricultural GDP, more than 90% and 80% respectively of the industrial and services GDP.

It is during this period of high rates of population growth that the country has also experienced substantial changes in its economy, and the industrialization process was intensified. With the exception of a brief period in the early 1960s, GNP has increased at a rate in excess of 5% per annum and by 1977 Brazil ranked as the eighth largest economy in the western world. Per capita GDP levels had risen from US$330 in 1950 to US$900 in 1980 in real terms (Dickenson, J. P., 1978).

Table III shows the shift in the relative distribution of the economically active population in Brazil, by sector, for the period 1960-1980.

TABLE III

RELATIVE DISTRIBUTION OF ECONOMICALLY ACTIVE POPULATION IN BRAZIL, BY SECTOR, 1960-1980.

Sector	1960	1970	1980
Primary	54.0	44.3	29.9
Secondary	12.9	17.9	24.4
Tertiary	33.1	37.8	45.7
TOTAL	100%	100%	100%

SOURCE: FIBGE, Tabulações Avançadas do Censo Demográfico, I, Tomo 2, 1980.

These figures presented in Table III indicate substantial decline in the primary sector over the period considered, manifesting a loss of 9.7% between 1960 and 1970 and an even larger one between 1970 and 1980 period of 14.4%, although this sector was still absorbing the greater share of the work force in 1970. Only in 1980, this sector loses its head position for the tertiary sector which presented a growth rate of almost 50% for the whole period (Wirth, D. et al. Ed., 1987).

The secondary sector was the one which grew most rapidly in relative terms, almost doubling its share between 1960 and 1980. In absolute numbers employment in the secondary sector increased 80% between 1960 and 1970 and doubled between 1970 and 1980, growing from approximately 2.9 million in 1960 to 5.3 million in 1970 and to 10.7 million in 1980 (Wirth, D et al. op. cit.).

Finally, the tertiary sector which absorbed a third of the labour force in 1960, expanded consistently until it included 45.7% of the economically active population in 1980. In absolute numbers the tertiary sector included 7.5 million individuals in 1960, 11.5 million in 1970 and 20 million in 1980, achieving a growth of 48% and 79% respectively for each of the periods 1960-1970 and 1970-1980 (Wirth, D et al. op. cit.).

Average real income rose by nearly 50% from 1970 to 1980. However the country development structure has done little to attenuate the high concentration of income and in 1980 the top decile of the income earning population appropriated approximately half of all income earned, while the share of income accruing to the lowest decile barely exceeded 15% of the total - see Table V (Wood, C. H. and Carvalho, J. A. M. 1988).

So all this economic growth and changes represented any gain for the population?

It seems that despite this high rate of economic growth, industrialization has made little impact on the pattern of income distribution. Also the industrialization has also failed to generate employment on a large scale. Failure to create jobs, coupled with continuing high rates of population growth plus a rural out migration, have increased the problems of urban unemployment and underemployment, and marginalized a considerable proportion of the urban potential labour force.

However there is little direct evidence to suggest that this fast population growth rates, has necessarily resulted in increased open unemployment. Reported unemployment rates for the nonagricultural labour force in the

1970 Census were very low, 2% or 3% (Merrick, T. W., 1979).

Brazil experienced from 1950 to 1970 an almost doubling of the population in the labour force entry ages- 10 to 24 years , especially due to the high birth rate, coupled with a mortality decline during the 40s and 50s. Such a growth has been representing a major challenge in the following years.

According to the 1989 National Household Research (PNAD- Pesquisa Nacional por Amostra de Domicílios), in 1989, unemployment accounted for 3% of the total active population of 60.6 million people which was considered very high. Also it was observed for the the period 1981 to 1989 a relative increase in the agricultural labour force formal market, and consequently a decrease in the informal market. Contrary to this in the same period, the opposite was observed among those engaged in nonagricultural activities as shown in Table IV.

TABLE IV

SHARE BETWEEN FORMAL AND INFORMAL MARKETS FOR AGRICULTURAL AND NON AGRICULTURAL ACTIVITIES- 1981-1989.

Agricultural Activities	1981	1989
Formal Market	13.3%	22.0%
Informal Market	86.7%	78.0%
Nonagricultural Activities		
Formal Market	67.1%	65.0%
Informal Market	32.9%	35.0%

SOURCE: 1989 National Household Research

If the main changes in the employment structure are reviewed it becomes clear that employment in the primary sector has decreased rapidly and simultaneously the employment in industry and in services had increased at a rapid pace.

These changes in the employment structure will lead to changes in the urban structure and land use. As figures for secondary and tertiary sectors presented growth, the employment generated by these two sectors will tend to be located within the more serviced areas where transport is already available. It seems logical that this process is self feeding, that means, the areas which are better serviced will attract new developments, and these new developments will demand more services or improvements in the services already provided. This process is endless.

These tendencies could be interpreted as resulting in a qualitative improvement in the conditions of labour in developing countries, as they represent a displacement of people from employment of low productivity and low pay to better paid and more productive jobs. However, in the Brazilian case they have been neutralized by the concentration of income and by the state's inadequate provision of collective consumption goods and services which were and are still required by a fast growing urban population.

Without taking into account the effects of the economic crisis the country faced from 1980 to 1984, it is enough to mention how living conditions of lower income groups deteriorated even before this crisis period. One could mention an increase in infant mortality during a good part of the

1970s, an increase in work-related accidents (either at work or on the way to work), a deterioration and insufficient growth of the urban transportation infrastructure despite all the investment in Metropolitan areas with rapid transits. Also a lack of investment in new housing stock is observed, especially for lower income segments. Nevertheless all the housing policies adopted in the country after 1964 with the creation of the National Housing Bank (NHB).

According to Kovarick (1987), one cannot often say that the recent process of accumulation of wealth has led necessarily to an absolute increase in impoverishment for a considerable proportion of the labour force. But certainly for the greater number of those workers who are unskilled or semi skilled, their wages have declined in real terms and consequently their standards of living may also have declined. In order to meet basic needs of food, shelter and transport, those workers earning one Minimum Wage monthly (approximately US$50) must work 466 hours and 36 minutes a month, or 16 hours a day for 30 days a month.

To give evidence of the degree of inequality and the concentration of income, Table V shows the percentage share of income by selected percentile groups for the period 1960-1980.

From Table V it is evident how income is concentrated and the gap between the richest and the poorest segments has become even greater in the last decade.

TABLE V

RELATIVE SHARE OF INCOME, 1960-1980

Percentile	1960	1970	1980
Poorest 50%	17.71%	15.05%	14.17%
Richest 10%	39.66%	46.47%	47.81%
Richest 1%	12.11%	14.11%	18.21%

SOURCE: Carlos Langoni, Distribuição de Renda e Desenvolvimento Econômico do Brazil, Rio de Janeiro, 1973.

What are be the demands at metropolitan or municipal level in a country such as Brazil? If at national level inequalities are observed, it is likely that they will also be apparent at the metropolitan and municipal levels. This study will concentrate in the city of Rio de Janeiro, for which a similar approach in presenting data on the study area is adopted.

II-2. RIO DE JANEIRO.

II.2.1. Introduction.

Rio de Janeiro is the second largest city in Brazil. Historically Rio de Janeiro was the country's capital from 1763 until 1960, when the capital was transferred to Brasília and Rio de Janeiro was transformed into a city-state of Guanabara. In 1975 Guanabara and Rio de Janeiro states were merged into the new State of Rio de Janeiro, and the the city of Rio de Janeiro was elected the capital of this new state. Nowadays Rio de Janeiro Metropolitan Region comprises 14 municipalities (Map II) and an estimated population of approximately twelve million inhabitants, from which almost seven million (Table VI) live in the Municipality of Rio de Janeiro. So Rio de Janeiro includes the State, the Metropolitan Region, the Municipality and the City. Every time the word is used without any reference it means the City of Rio de Janeiro, otherwise it will be stated.

The research area of study is the city or the municipality of Rio de Janeiro.

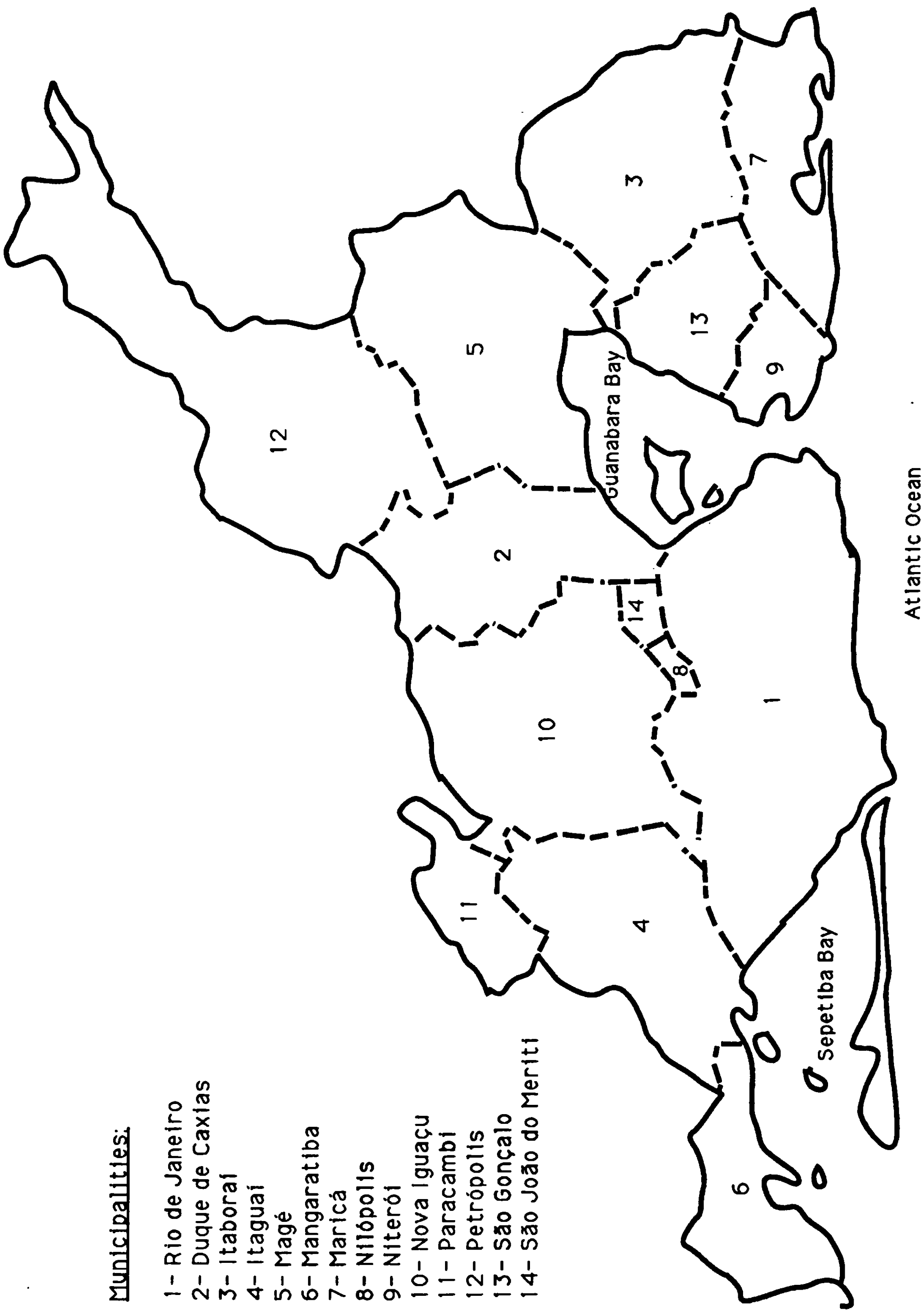
II.2.2. Historical Background.

During the nineteenth century the city of Rio de Janeiro was a crowded and unhealthy port, subject to frequent quarantines and inhabited largely by petty aristocrats, Negro and mulatto masses (Conniff, M. L. 1981).

By the turn of the century, Rio de Janeiro was a city whose quality of life was seriously threatened. So by the beginning of this century a comprehensive urban and sanitation plan was undertaken by Federal and Local authorities, inspired partially by the successful renewal plan that took place in Paris by Georges Haussmann. The city centre experienced a clearance programme and it was opened to traffic, which later served as axis for new projects (Conniff, M. L. op. cit.).

By that time the centre was a walking city, as most people lived in or near their workplaces. In 1906, 256,000 people lived in Rio de Janeiro's central area, or approximately 32% of its total population (Conniff, M. L.

MAP II - RIO DE JANEIRO METROPOLITAN REGION



op. cit.).

In 1920 the city site was essentially a semi-circle, with a radius of approximately seven kilometres from the northwest edge of the city clockwise to the south shore of Guanabara Bay (Conniff, M. L. op. cit.).

The so called North Zone comprised of the neighbourhoods of São Cristóvão, Tijuca, Vila Isabel and Engenho Velho, where 246,000 lived according to the 1920 Census, while on the southern part of the city laid other old neighbourhoods, namely Lapa, Glória, Flamengo, Botafogo and Santa Teresa. Flamengo and Botafogo accounted for 12% of the population or 131,000 inhabitants. These older neighbourhoods, where approximately one third of the city's population lived, had become transitional zones full of slums, night clubs districts and factories and later were abandoned by the most affluent residents (Conniff, M. L. op. cit.).

Beyond the North Zone districts lay the Suburbs, a score of new neighbourhoods that were remarkably developed in 1910s and 1920s, mainly due to the provision of railway services along four principal rail tracks, linking these areas to the main core. Most of the developments occurred close to the train stations. According to the 1920 Census, the population in suburban Rio was 414,000 people (Conniff, M. L. op. cit.).

Despite this demographic increase, suburban areas were already facing serious problems by that time, such as lack of transport and services at night. The main reason for the deterioration of these peripheral areas lay mainly in the diversion of public investment to other parts of the city. In essence the city had never provided sufficient services for such a large population; commuter trains, streets, utility grids, schools, clinics were either forgotten or allowed to languish (Conniff, M. L. op. cit.).

By that time the Government owned Central do Brasil railway was already operating in very poor conditions; most of the equipment dated from the previous century, the beds were uneven, the rolling stock was slow and unsafe (in 1926 an average of one accident a day was recorded and riots occurred occasionally) and the system capacity was not sufficient to cope with its current demand by then. In 1920 the US$ 20 million borrowed from the United States for the electrification of the system was diverted for developments that took place within the Core area; the Castelo Hill project (Conniff, M. L. op. cit.).

The diverted public funds from peripheral areas were mainly allocated in the South Zone of the city, a new elite residential area along the beaches of Copacabana and Ipanema. Copacabana became the place to live by an emerging upper middle class and upper class. Land values rose by as much as a thousand times in the 1920s. In 1920 there were 38,000 people living there and for the following twenty years, this area was the fastest growing in the city at average rates of 6.3% per annum (Conniff, M. L. op. cit.).

The development of this area of the city required substantially higher public investment than peripheral areas. Landfill and tunnels, tide walls, new utilities, roads, parks and beach facilities took up the majority of the available funds from the city budget during the 1920s (Conniff, M. L. op. cit.).

The rise of the South Zone caused the eclipse of the North Zone, which could not no longer compete for state investment and lacked the elegant symbols of the sea side districts (Conniff, M. L. op. cit.).

New housing stock for the growing population was mainly financed privately by family savings, consequently only those with a steady income above subsistence levels could afford it. For the poor there were basically three housing alternatives: the older manor houses, abandoned by their previous owners, which were converted into rooms; illegal subdivisions in peripheral areas and lastly, squatter settlements mainly located on hillsides in central areas (Conniff, M. L. op. cit.).

It is important to stress that those squatter settlements flourished at a rapid pace in Rio de Janeiro (between 1920 and 1933 the number of slum dwellings rose sixfold in Rio, and grew at an average annual rate of 14%), and soon became the refuge of the working classes and recent migrants (Connif, M. op. cit.). This housing alternative was very tempting; it was close to the city centre and no tax or rent was required (Câmara, A. P. R., 1986).

Is it possible to establish to what extent the location of the labour market has influenced the location and proliferation of these squatter settlements in Rio de Janeiro? According to the 1948 Census, 59%, 76% and 77% of the slums dwellers respectively living in the Northern Zone and Suburbs, Central Area, and finally in the Southern Zone also worked there (Parisse, L. 1969), providing some evidence that dwellers tended to trade off housing and work locations. The next section presents the population growth and welfare distribution.

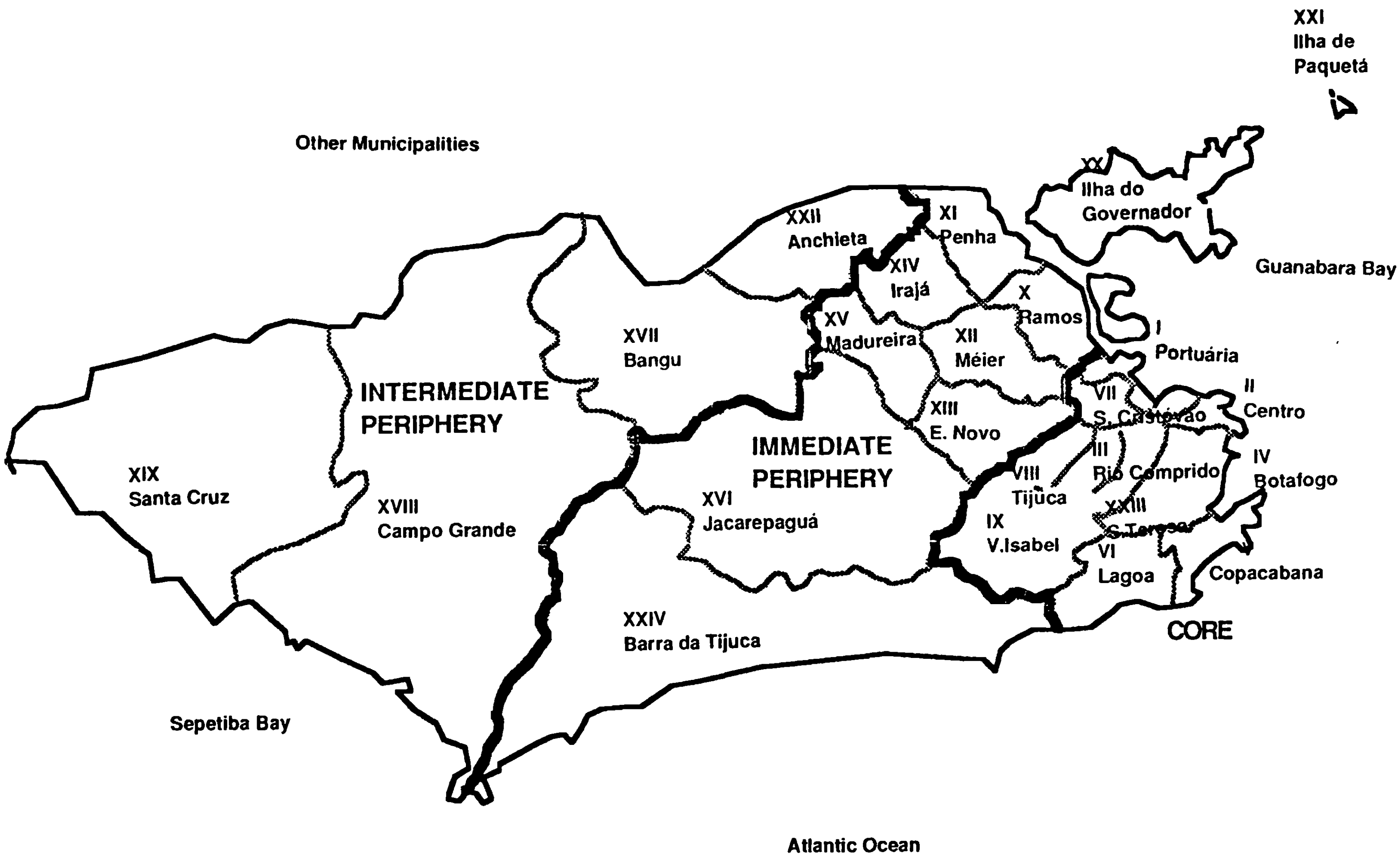
II.2.3. Population Growth and Wealth Distribution.

Population growth and wealth distribution in Rio de Janeiro reflects that of the country overall. In other words the city experienced a significant growth in population, income concentration and, moreover the concentration of wealth is spatially segregated within Rio de Janeiro's urban boundaries. From the previous section it is possible to observe that this spatial segregation has been historically reinforced. This section presents data from secondary sources that will support this argument, such as income, car ownership and educational background.

Rio de Janeiro is divided into 24 administrative bodies called Regiões Administrativas (RAs) which play no role at all from the political or administrative points of view, but are adopted in this study because most of the census data is aggregated with the RAs as the main cells. Another aggregation is also adopted for methodological reasons and because a similar pattern of aggregation has been used in much previous research concerning Rio de Janeiro. This other grouping comprises three macro areas; Core, Immediate Periphery and Intermediate Periphery. For studies that include the whole Metropolitan Region a fourth area is usually considered; Distant Periphery. All these peripheries are concentric to the main core. Map III shows this spatial distribution.

Rio de Janeiro municipality population corresponded to 76% of the metropolitan region population in 1940. In 1980 this figure dropped to 56%, mainly because the other municipalities of the metropolitan region experienced higher population growth rates (Prefeitura Municipal do Rio

MAP III- RIO DE JANEIRO MUNICIPALITY AND ADMINISTRATIVE REGIONS



de Janeiro, 1988). If the population growth of Rio de Janeiro is analysed, it is observed that the highest growth rate happened in the period from 1950-1960, both in the Metropolitan Region and in the Municipality, coinciding with the acceleration of the industrialization process that took place in the country, and also the migratory flows from rural areas towards urban areas. At a national level the main migratory flows were from the Northeast to the Southeast, mainly to São Paulo and Rio de Janeiro Metropolitan Areas.

Table VI shows the population distribution and growth rates, for the Metropolitan and Municipality of Rio de Janeiro for the period 1940-1989.

<u>TABLE VI</u>

<u>POPULATION DISTRIBUTION IN RIO DE JANEIRO METROPOLITAN REGION AND MUNICIPALITY, 1940-1989</u>

Year	Metropolitan Area	Growth Rates	Municipality	Growth Rates
1940	2,316,638	-	1,764,141	-
1950	3,290,465	42.9%	2,377,451	34.2%
1960	5,024,919	52.7%	3,307,163	39.1%
1970	7,080,661	40.9%	4,251,918	28.6%
1980	9,018,637	27.4%	5,073,232	19.3%
1989*	12,745,300	41.3%	6,959,800	37.2%

SOURCE: FIBGE, Demographic Census, 1940-1980.

*FIBGE, Demographic Studies Brazilian Centre, 1989 (estimate figures)

As the area of study is the city of Rio de Janeiro, detailed figures are shown in Table VII for population distribution taking into account the two aggregation levels that are considered in this work. At a more aggregated level the three areas of Core, Immediate and Intermediary Peripheries and in a more disaggregate level, the Administrative Regions are used.

TABLE VII

RIO DE JANEIRO POPULATION DISTRIBUTION AND GROWTH RATES

Administrative	Population (x 1,000)		Growth
Region	1970	1980	Rates
1- Core	**1,383**	**1,446**	**4.5**
I- Portuária	51	46	-9.7
II- Centro	59	55	-7.3
III- Rio Comprido	96	93	-2.9
IV- Botafogo	256	267	4.5
V- Copacabana	239	228	-4.6
VI- Lagoa	175	216	23.2
VII- São Cristóvão	90	93	3.7
VIII- Tijuca	192	205	7.0
IX- Vila Isabel	157	177	12.6
XXIII- Santa Teresa	64	61	-4.8
2- Immediate Periphery	**1,939**	**2,291**	**18.1**
X- Ramos	234	255	8.8
XI- Penha	286	315	10.0
XII- Méier	364	411	12.8
XIII- Engenho Novo	195	207	6.2

2- Immediate Periphery	**1,939**	**2,291**	**18.1**
XIV- Irajá	240	273	13.8
XV- Madureira	267	277	3.7
XVI- Jacarepaguá	216	326	50.7
XX- Ilha do Governador	105	171	62.0
XXI- Ilha de Paquetá	3	2	-31.8
XXIV- Barra da Tijuca	24	50	106.3
3-Intermediate Periphery	**928**	**1,352**	**45.6**
XVII- Bangu	372	530	42.4
XVIII- Campo Grande	230	333	45.0
XXII- Anchieta	233	337	44.8
XIX- Santa Cruz	92	151	62.8
TOTAL	**4,251**	**5,090**	**19.7**

SOURCE: FIBGE, Demographic Census, 1970,1980.

From Table VII it is clear that the Core have presented lower growth rates than the Peripheral areas. In some Administrative Regions even a negative rate was observed that could be explained mainly by the change of land use from residential to services, especially in the central area of the Core, represented mainly by the two first Administrative Regions, Portuária and Centro. Lagoa and Vila Isabel RAs were the two that have presented significant growth rates, explained by the intensification of the residential use, mainly by the process of high rise building experienced within their boroughs. Overall the low growth rates observed within the Core are due to lack of land and as well as its high price. The city grew towards peripheral areas as growth rates were respectively 18% and 46% for Immediate Periphery and Intermediate

Peripheries.

Rio de Janeiro was the largest industrial centre of Brazil until the 1940s and concentrated over a quarter of a million industrial workers. By that time in its role as federal capital was a major attraction to early industrial development and as late as 1920, 20% of the country's employees in industry were settled there. By 1975, this figure had fallen to only 8.5% (Dickenson, J. P. op. cit.).

The manufacturing industries of Rio de Janeiro have developed essentially in response to its dual role as a major concentration of population and as a port, so that consumer industries for its population and processing activities associated with import and export commodities have been important (Dickenson, J. P. op. Cit.).

At the beginning industry was on a workshop scale and clustered in the area of the original settlement, which today corresponds to the central area of the Core. With population growth and transport developments this original industrial land use was banned from the centre and forced to peripheral areas and then industrial activities expanded on a factory scale.

Data from 1975 shows the importance of the city of Rio de Janeiro within the metropolitan context. The GDP of the city corresponded to 76% of the GDP of its metropolitan area. If this figure is broken down by activity, the tertiary sector corresponded to 80%, while the secondary to 74% and the primary sector shared only 30% (Prefeitura Municipal do Rio de Janeiro op. cit.).

The employment distribution in industries at the metropolitan level is as follows; 75% in Rio de Janeiro and the remaining 25% within the other 13 municipalities of the metropolitan region (Prefeitura Municipal do Rio de Janeiro op. cit.).

In 1980, Rio de Janeiro's active population was approximately 2 million people, or 40% of the whole population. This figure gives an average of two economic active members per household. Recent trends in the local economy allows the following statements (Prefeitura Municipal do Rio de Janeiro, op. cit.);

1- The economically active within the primary sector is declining, giving evidence of the urbanization level the city has achieved.

2- The economically active in the secondary sector is the one that presented the highest growth rates in the period 1960-70-80.

3- The economically active in the tertiary sector is the one that presented the lowest growing rates in the same period, although it accounts now for 73% of the total economically active population.

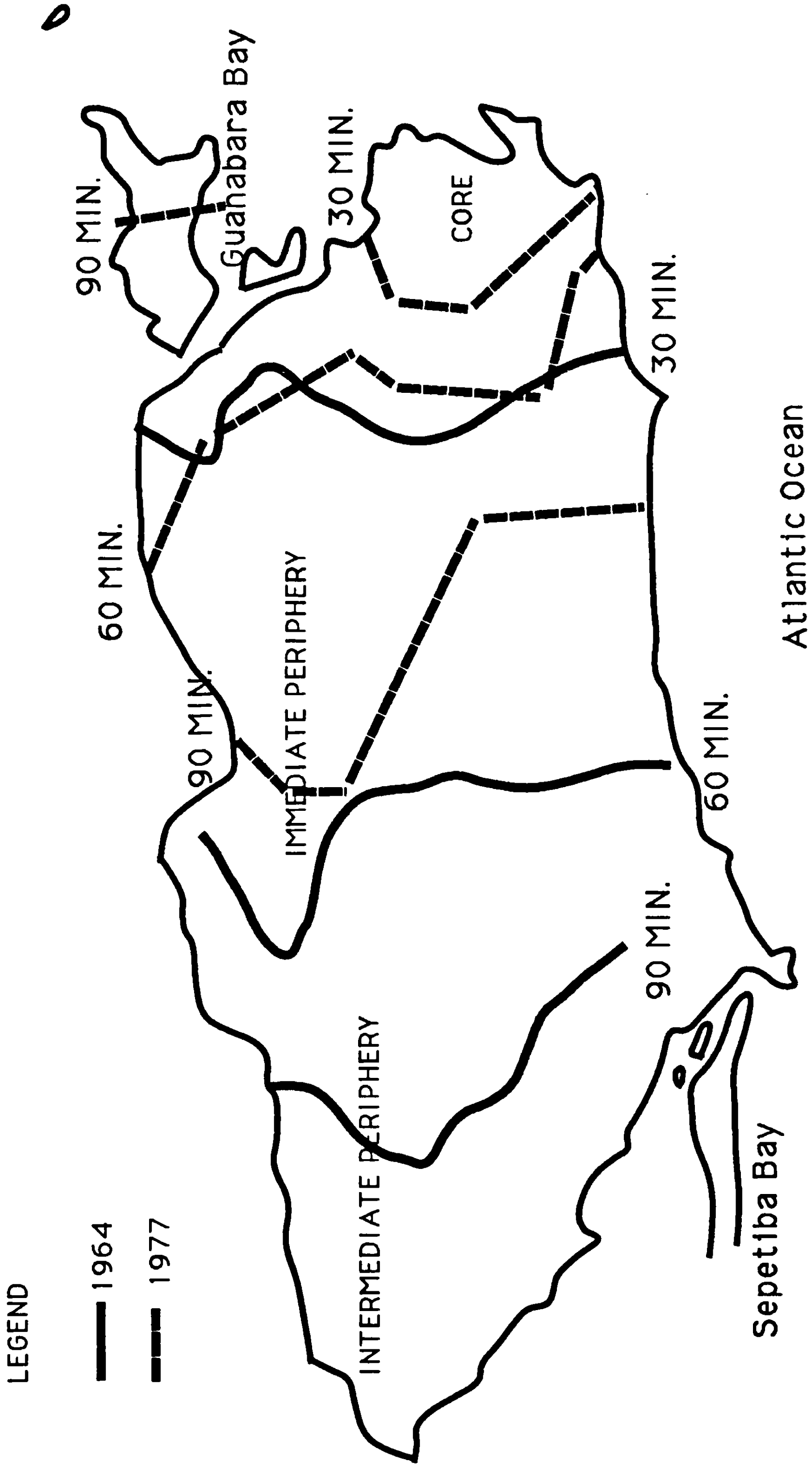
The spatial distribution of the activities is so that the Core concentrates 60% of the job market and both peripheries share figures of about 20% each. In absolute numbers the Core generates 900,000 jobs. If on the other hand the spatial distribution of the active population among these three areas is analysed, only 30% of the total inhabit the Core while in Immediate Periphery and Intermediate Periphery the corresponding figures are 38% and 32%, resulting in an imbalance between housing and job market locations.

When the implication of this spatial distribution of the labour market and labour force may have in travelling time is analysed, a very interesting picture emerges. If three travelling time isochrones (by bus) are considered (figures refer to 1977), concentric to the Core of 30, 60 and 90 minutes, one will find that within the first isochrone 900,000 inhabitants resided, within the second one, 1,100,000 inhabitants, leading a total figure of 2 million inhabitants within an hour by bus from the core. However between the second and third isochrones a population of 2,2 million inhabitants is found. If the same isochrones are compared to figures for 1964, it is concluded that travelling times have increased significantly or in other words, the distances covered within each isochrone have decreased, showing that higher levels of car ownership and congestion have caused living standards to deteriorate substantially by increasing commuting time, especially from peripheral areas to the core (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, 1977). Map IV shows the isochrones referring to 1964 and 1977.

The periphery in Brazilian cities has emerged out of the process of economic development experienced in the country in the last few decades and as a formula for reproducing the labour force (Kovarick, L. 1987). The city of Rio de Janeiro is no exception.

This process of sub-urbanization (urban scale enlargement) leads necessarily to a process of spatial specialization and segregation; concentration of certain kinds of industry in specific parts of the town and concentration of certain strata of the population in other specific parts of

MAP IV - TRAVELLING TIME BY BUS ISOCHRONES



the urban area. Specialization and segregation also lead for example, to greater distances between home and work (Boer, E., 1986).

The pattern of activity distribution in Rio de Janeiro seems correlative with the patterns of growth or changes experienced within the three sectors of the local economy which means concentration of secondary and tertiary sectors' activities in areas better serviced with infrastructure.

The Core also concentrates 54% of the total income, reflecting at a local level the national pattern of income concentration and uneven distribution.

Other inequalities amongst these three areas could also be pointed out such as car ownership, land values, population educational background, and provision of public services such as piped water, electricity and sewage. Table VIII shows the car ownership levels and land values for the three areas in concern per square metre.

TABLE VIII

CAR OWNERSHIP LEVEL AND LAND VALUES

Area	Car Ownership (x 1,000)	Land Values (m^2)*
Core	644.2	4,993
Immediate Periphery	582.5	1,074
Intermediate Periphery	113.7	93

SOURCE: 1989 Forecast from the Census. * 1975 Figures in Cruzeiros (Brazilian Currency), compiled by the author.

Although figures from Table VIII relates to different periods of time, it is clear that land values and car ownership levels are highly concentrated within the Core, to the detriment of the two peripheries. The prices of land are certainly under the influence of market forces and in the Core the lack of available land and the concentration of services and infrastructure raises the prices significantly. On the contrary, in the peripheral areas, the lack of infrastructure and the abundance of land lowers the prices. Higher car ownership levels within the core is highly correlative with income concentration. This relationship will be detailed later.

To reinforce the unequal distribution of public services among the three areas, Table IX shows the percentage of dwellings served with piped water, electricity and sewage systems in Rio de Janeiro.

TABLE IX

DISTRIBUTION OF BASIC SERVICES

Area	Piped Water	Electricity	Sewage
Core	81.6%	97.2%	73.9%
Immediate Periphery	80.7%	94.5%	33.9%
Intermediate Periphery	59.6%	88.6%	4.0%

SOURCE: 1980 National Census, Rio de Janeiro, 1983 - compiled by the author.

From Table IX it is observed that the Core is well serviced and that the other areas suffer a reduction in all the services concerned, especially piped water and sewage systems in Intermediate Periphery. This is mainly due to a concentration of illegal subdivisions in this area.

When educational backgrounds are checked among the population, figures are consistent with those already presented. According to the Census four educational categories are considered; elementary school (ES), primary school (PS), both compulsory by law to all children from the age of 7 until 14, secondary school (SC) and higher degree (HD). Table X shows the spatial distribution of the population according to their educational background.

TABLE X

POPULATION EDUCATIONAL BACKGROUND SPATIAL DISTRIBUTION.

	Educational Background				
Area	ES	PS	SC	HD	Subtotal
Core	335,421	216,282	264,775	187,805	1,004,283
	33.40%	21.50%	26.36%	18.70%	100%
Imm.Per.	690,663	330,679	254,901	76,415	1,352,658
	51.05%	24.45%	18.84%	5.65%	100%
Int. Per.	412,852	162,317	86,521	14,319	676,009
	61.07%	24.01%	12.79%	2.12%	100%
TOTAL	1,438,936	709,278	606,197	278,539	3,032,950

SOURCE: FIBGE, 1980 National Census, Rio de Janeiro, 1983, compiled by the author.

Table X is very important by the fact that it really shows how access to education is related to income levels, in a way that lower income dwellers have to start work earlier than those in higher income groups. On one hand as a result of the concentration of higher income groups within the core, one will find that 67% of those with higher degree live within the Core. On the other hand, in the peripheries it is observed that higher percentage of population with lower level of educational attainment. This pattern seems to reinforce the distribution of the population in a way that those with lower educational background will have access to lower paid jobs, and lower paid jobs will lead to lower access to education.

Lower income will also reduce the possibility of access to accommodation in better serviced areas, and to make use of the amenities offered in the Core.

Up until now the transport issue has not been discussed in detail. In this introduction the main objective is to give a picture of how population is distributed in a segregated way within Rio de Janeiro, and then to enter deeply into the analysis of the city transport system.

However the growth of the urban structure and the development of transportation have both created great problems for public transport, and these have usually taken the form of economic difficulties for operators and local authorities, and decreasing standards of travel. The standards of public transport and its economics depend ultimately upon the urban travel patterns, which in turn are controlled primarily by the income and household distributions, and the urban structure of the area (Lagerquist, G., 1979).

Population socioeconomic spatial distribution is presented in Table XI in five different income categories by Monthly Minimum Wages (The Minimum Wage- MW was established in 1939, with the purpose of meeting costs of basic needs of the working class in Housing, Education, Food, Clothing, Health, Transportation and Leisure; on average the Minimum Wage value fluctuates around US$50, per month; Transport expenses were estimated to compromise up to 6% of one Minimum Wage. Since its creation the Minimum Wage has been loosing its purchasing power significantly). Here to emphasise how income is concentrated, even within the Core, this area has been further divided into three sub-areas because they present substantial differences. These sub-areas are: Central Area, Northern Zone and Southern Zone.

TABLE XI

POPULATION SOCIOECONOMIC SPATIAL DISTRIBUTION

Area	Income	Categories			
I- Core	< 1MW	1-3MW	3-5MW	5-10MW	>10MW
Central Area	1.8	2.6	3.0	2.7	1.2
Northern Zone	11.6	10.3	11.6	15.2	19.8
Southern Zone	13.4	13.8	15.8	23.7	47.0
Sub-total	26.8	26.7	30.4	41.6	68.0
II- Imm. Per.	45.4	44.9	46.5	44.2	28.4
III- Int. Per.	27.6	28.2	23.1	14.2	3.7
TOTAL	100%	100%	100%	100%	100%

SOURCE: FIBGE, 1980 National Census, Rio de Janeiro, 1983, compiled by the author.

From Table XI, the socioeconomic segregation of the population becomes more evident; it is observed that 68% of those within the highest income category live in the Core, from which 47% in the Southern Zone. If the lowest income category is considered; only 27% of the total population live in the Core, while 45% and 28% respectively live in the Immediate and Intermediate Peripheries.

What should be the findings of this description of wealth distribution in Rio de Janeiro? How is access to higher income determined? What is it the logic of this segregative process that limits access to education, and lower education on the other hand limits the access to better paid jobs, and lower income will reinforce limited access to higher education? Parallel to this, lower income will also determine where people will live.

Given this spatial distribution of the active population and activities among the three areas, it is expected that a great many trips will be generated daily and that the Peripheral areas will turn to be the main pole of trip generation, while the Core will be the main pole of trip attraction.

What modes of transport are available? How is demand split among the available modes? In Chapter III a detailed picture of Rio de Janeiro transport system is given.

CHAPTER III- THE TRANSPORT SYSTEM

III.1- INTRODUCTION.

According to the 1988 Federal Constitution regarding the social rights section, article No. 7, item IV, transport is one of the basic needs such as shelter, health, education, clothing, hygiene, social security and entertainment and that the minimum monthly wage should guarantee the workers access to it. On the other hand according to article No. 22, items IX and XI , it is the State role to legislate concerning transport national policies and traffic and transport. Usually transport operation is granted through concession or any other legal instrument to the private initiative, by local Government or authorities.

The transport system has played and still plays an important role in the urbanization process in Rio de Janeiro, and also in the distribution of both activities and population.

Ever since the domestication of the horse, transport technology has created differences in mobility between population categories. These differences sometimes have been reflected in the way classes were socially structured (Nijkamp, P. 1987).

For example the first spatial differences cited by Nijkamp (op. cit.) were caused by the railway, easing the access and mobility of those living close to the stations. More recently with the advent of car ownership, once more population was divided into two groups; the mobile and unmobile strata, the latter being the dependent on the public transport, that in turn is not always evenly accessible to all segments of the population.

Table I shows journeys modal spilt by public transport for the Metropolitan Region of Rio de Janeiro, for the period from 1944 to 1986 .

TABLE I

RELATIVE JOURNEYS MODAL SPLIT BY PUBLIC TRANSPORT IN RIO DE JANEIRO METROPOLITAN REGION. (1944-1986).

Mode	1944	1954	1964	1975	1980*	1982*	1986
Tramway**	68.2	56.3	22.4	-	-	-	-
Bus	12.9	20.2	48.3	88.8	87.1	80.9	80.1
Train	16.8	20.7	25.5	7.2	11.5	12.9	11.8
Boat***	2.1	2.8	3.8	4.0	na	na	2.6
Underground	-	-	-	-	1.4	6.2	5.5
TOTAL	100%	100%	100%	100%	100%	100%	100%

SOURCE: Barat, Josef- Estrutura Metropolitana e Sistema de Transportes- Estudo do caso do Rio de Janeiro, IPEA-INPES, 1975.

* Figures for 1980 and 1982 are forecasts from PITMETRO, Plano Integrado de Transportes, 1976, Rio de Janeiro.

** There is still a tramway service operating by the Bus Public Operator CTC-RJ, from the CBD to the borough of Santa Teresa, in the Core.

*** This system operates mainly between the Municipalities of Rio de Janeiro and Niterói. A municipal link was created recently.

From the figures presented in Table I it is observed that up to 1964 Rio de Janeiro still had the tramway as a mode of transportation. This mode was dominant until the 1950s, when the bus and the train shared a smaller percentage of the total demand. But the bus mode experienced a constant increase in its share among the other modes, achieving its peak by 1975, almost 90% of the total demand. In the following years the bus experienced a slight decline, explained mainly by the introduction of the underground system and to some improvements in the railway system that took place after 1975.

The underground system started operating in 1979, and initially it shared only 0.4% of total demand. By 1982, with the partial expansion of its network and the opening of new stations, the system achieved its peak. By 1986 the underground experienced a decrease in demand, and probably today the underground shares only 5% of the total. The small participation of this mode can be explained by the non completion of the basic planned network, the result of which is that the bus still competes with this mode. Moreover, since 1987 the underground single fare has been higher than the equivalent fare on the bus.

The train shared the second largest demand in 1954, but has subsequently experienced a significant decrease, explained by many factors such as no regularity on the services, lack of comfort and no investment for improvements before 1975 and the increased level of bus competition. By 1975, when the bus achieved its maximum and the train its minimum participation at the modal split. After that year, the train recovered its share slightly achieving figures of 12%. The train caters mainly for the suburban demand.

Finally there is the boat system, which has never been a representative mode, but its main characteristic is that it has been able to keep its share almost constant along the years without any significant change. In fact the boat system meets the demand of those who live in the eastern metropolitan municipalities on the other side of Guanabara Bay. Another feature of the boat system is that it is the only mode to operate scheduled services on a regular basis.

In 1980 the Rio de Janeiro Metropolitan Region journeys vehicular trips modal split, considering the private transport was as follows: bus 65.76%; private car 24.5%; train 8.68%; and underground 1.06%.

Before going into detail of each of these modes of transport, some historical aspects of the urbanization process in Rio de Janeiro and the role that transport has played within this process, acting not only as a promoter but also being promoted by this process is advisable.

III.2 - HISTORICAL BACKGROUND.

Transport played a crucial role in Rio de Janeiro's urbanization process and two modes of transport were mainly responsible for the sprawl of the urban fabric. These were the train and the tramway. While the first developed the suburban areas, the latter developed the central area and towards the seaside.

In 1858 the first track of D.Pedro II Railway (today, Brazil Central Railway) was inaugurated, linking the borough of Santana in the central area to Queimados in the far suburban area. Also in the same year some stations were inaugurated on the route such as Cascadura, Engenho Novo (both in Rio de Janeiro) and Maxambomba (in the municipality of Nova Iguaçu). Many other stations were opened in following years. In 1861 a regular service was operating between the main Central station and Cascadura, leading immediately to the occupation of sites between the two areas, previously rural land. This area attracted those searching for cheap housing, which resulted in an increase of demand for transport and the need for more trains and stations. In the decade 1860-70, other stations such as Riachuelo and Todos os Santos were also opened (Abreu, M., 1988).

In 1870 the Cascadura branch started being served with two other daily services, and schedules were adjusted to working hours. As an immediate consequence the sites along the tracks were occupied at ever increasing rates and this led to the opening of more stations, such as Engenho de Dentro, Piedade, Rocha and Méier among others (Abreu, M. op. cit.).

At the beginning this suburban occupation process had a linear form along the tracks, and a concentration of the dwellings around the stations was observed. Later with the opening of secondary streets perpendicular to the track, a radial occupation was permitted and this had increased significantly over the years (Abreu, M. op. cit.).

In the 1880s another two railways were created. In 1883 a temporary link was opened by Rio D'Ouro Railway to transport building material for the construction of the Water Treatment Plant. Later it was also used as a regular service for passengers (Abreu, M. op. cit.).

In 1886 Rio de Janeiro Northern Railway Company opened its first line between São Francisco Xavier and Mirity (in the municipality of Duque de Caxias). This railway became later Leopoldina Railway, and together with D.Pedro II Railway played an important role in the expansion of Rio de Janeiro towards the suburbs and rural land (Abreu, M. op. cit.)

The first tramway link was implemented in 1868, the vehicles being pulled by animals. This mode of transportation was fundamental in the Rio de Janeiro urbanization process and in 1946 the tramway network was already 430 kilometres long.The first links were set towards the sea side and the southern zone of the city.

The concession for this first tramway link was granted to the American Botanical Garden Railroad Company which started its services with the link from Gonçalves Dias Street to Machado Square, both places located within the actual core, serving the borough of Glória which was already a high income residential area. In 1871 the link was extended up to the Botanical Garden, and then the aristocratic borough of Botafogo also benefited from this service, the whole link stretching 13 kilometres. In the same year another branch was opened to Laranjeiras, but an affluent borough. By that time the company was transporting 3 million passengers a year (Abreu, M. op. cit.).

The success of Botanical Garden Railroad Company led to the creation of other similar companies, which obtained permission to provide services in other areas of Rio de Janeiro (Abreu, M. op. cit.).

In 1870 another company, the Rio de Janeiro Street Railway Company, started operating another branch serving boroughs located towards the northern zone such as São Cristóvao, Tijuca, Caju and Rio Comprido among others (Abreu, M. op. cit.).

In 1872, Botanical Garden started operation in another branch towards Gávea (Abreu, M. op. cit.).

Both systems were manly controlled by foreign capital, and each mode separately was important in the expansion of the city in opposite directions. The trains served mainly distant areas and dwellers that moved away from the central areas, because they could no longer afford living there, while the tramway served those dwellers that remained in the central areas and demanded a more regular and faster transport system.

By attending to this demand the tramway influenced not only the occupation pattern of the land, but also stimulated the accumulation of capital within the areas they served. Investments were made by traders, financiers and the aristocracy in properties located in areas served by the tramway.

So trains and tramways made possible the expansion of the city in different directions, allowing the consolidation of the gulf between the core and the periphery that was already emerging in the 1870s and that has been reinforced so strongly along the years.

The next sections present a description of the train, underground and the bus system in Rio de Janeiro to outline the actual figures on how each of these systems operate in Rio de Janeiro, which demand they serve and also some figures related to the private transport.

III- 3. THE RAILWAY SYSTEM.

III.3.1. Introduction.

Suburban rail services often share tracks with inter-city passenger trains and freight trains. They may use either heavy rolling stock similar to the the ones used by the inter-city trains or metro type vehicles (World Bank, 1986).

Benefits may be obtained when suburban sections of inter-city rail systems are allocated to provide fast, high capacity and reliable commuting service, although some kind of upgrading of the system is necessary, like electrification, improved platforms, new track, control systems and new rolling stock (World Bank, op. cit.).

The capacity of the suburban rail will depend upon the amount and type of track sharing, but on average a typical system may carry an hourly volume of 10,000 to 20,000 passengers in one direction. This capacity may be compared with those of the rapid rail system, if operated with exclusive use of the tracks (World Bank, op. cit.).

Journey speeds are also influenced by the type of the vehicle in operation and the gap between the stations, which may vary considerably. When operated by metro type vehicles and station spacing between 2 and 3 km, speeds may reach up to 45 to 55 Km-h (World Bank, op. cit.).

As previously stated the railway system played a crucial role in the urbanization process in Rio de Janeiro, and the occupation of suburban areas. As a result of this characteristic of this system, it is not possible to consider this mode of transportation exclusively within the boundaries of the city of Rio de Janeiro, but within the boundaries of the Metropolitan Region.

The management of the system is on behalf of Companhia Brasileira de Trens Urbanos, CBTU, whose task is mainly the operation of urban trains for passengers. The company is a subsidiary of Rede Ferroviária Federal (RFFSA), related to the Ministry of Transport.

The Rio de Janeiro rail suburban network dates mainly from 1923, and it was last upgraded in 1943. In 1975, 408 out of 819 carriages or 50% of the fleet was under repair (Moises, J. A. and Martinez-Alier, V. 1978). By 1987, the revenues from the fares did not cover more than 30% of the operational costs.

III.3.2. The Network Distribution.

The railway network at the Metropolitan Region is 740 kilometre long, from which only 143 operates within the Municipality of Rio de Janeiro.

From the total figures, 360 kilometres are double tracks while 400 kilometres are electrified. The Rio de Janeiro Metropolitan Region is served with six subsystems that are (Hosken, C. 1988):

1- Deodoro Subsystem: This branch covers 22 kilometres with two lines and links the Core (D.Pedro II Station) to Deodoro (Intermediate Periphery), stopping on the way at 17 intermediary stations. This subsystem runs exclusively within the city of Rio de Janeiro.

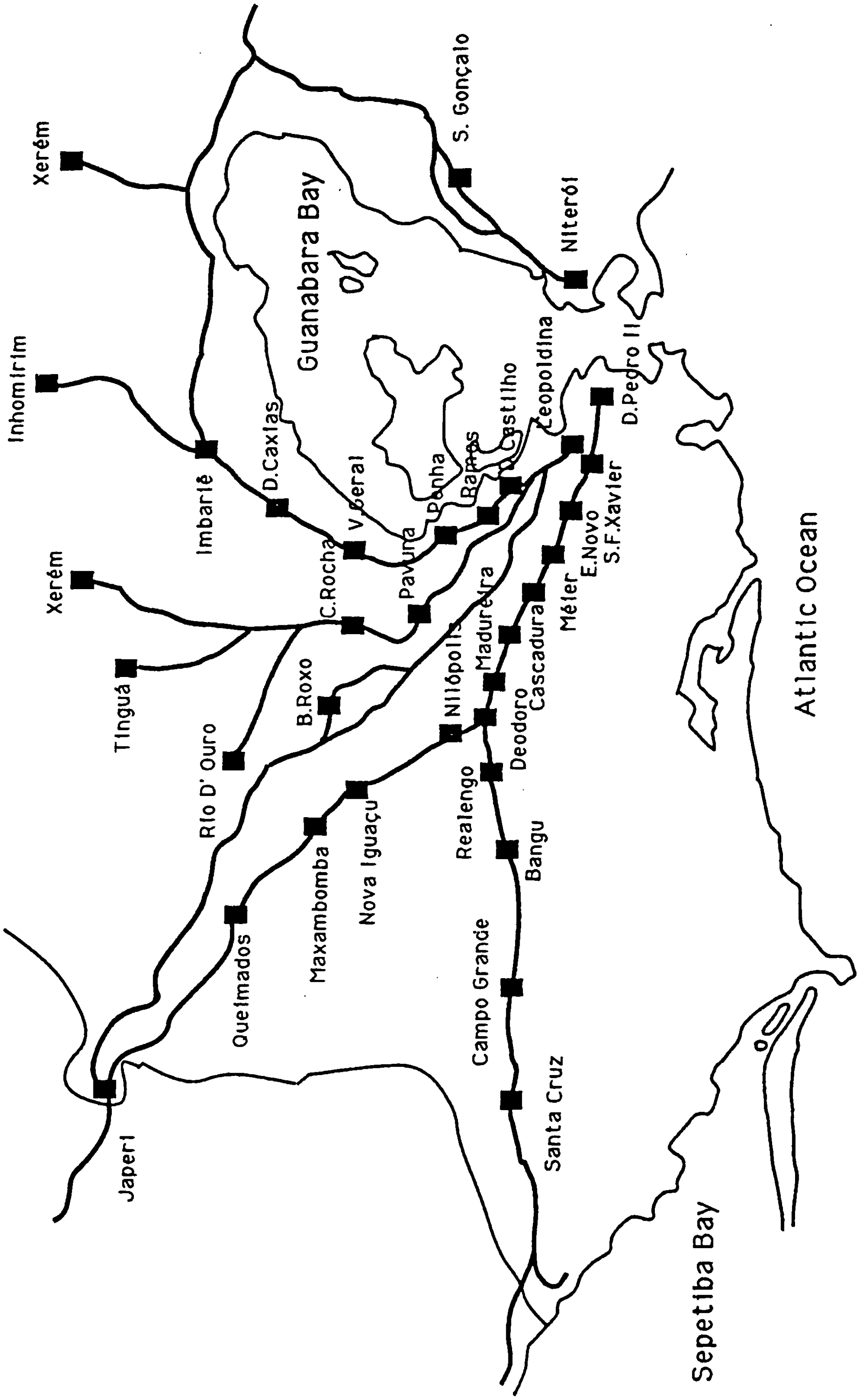
2- Japeri Subsystem: This subsystem is the continuation of the first one. From Deodoro onwards the branch is 48 kilometres long and the final destination is Paracambi in the Metropolitan area, serving 15 stations en route.

3- Santa Cruz Subsystem: Similar to the second one it is divided in two branches, being the first one the Deodoro subsystem itself. The second branch is 32 kilometres long, serves 16 stations and links Deodoro to Santa Cruz, both at Intermediate Periphery. This link operates exclusively within Rio de Janeiro boundaries. Since June 1986, an extension has been operating from Santa Cruz to Itaguaí, in the Metropolitan area.

4- Leopoldina Subsystem: This subsystem links the Core (Barão de Mauá Station) to Gramacho, in the Metropolitan area; it is 23 kilometres long and serves 13 stations.

5- Auxiliary Subsystem: This is an alternative branch for Deodoro and Japeri subsystems. It links the Core to Belford Roxo (Metropolitan

MAP V - RIO DE JANEIRO METROPOLITAN REGION RAILWAY NETWORK



Region), serving 17 stations and it is 33 kilometres long.

6- Narrow Gauge Subsystem: This system runs exclusively within the Metropolitan area in a total network of 103 kilometres, in continuation of Leopoldina and Auxiliary subsystems.

III.3.3. The Demand.

According to CBTU, the system as a whole is operating close to the maximum capacity limit, and potential demand was estimated to be half of the effective demand in 1987. According to PUB RIO, the railway system catered in 1975 for about 5.1% of the total passengers transported in the Metropolitan Region of Rio de Janeiro (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.).

The railway demand is mainly from suburban dwellers and also those living in the boundary municipalities of Rio de Janeiro, such as Nova Iguaçu, which is a typical example. Located 36 kilometres from Rio, its population reaches almost one million inhabitants from which only 14 thousand work in local industries and approximately 85% work in Rio de Janeiro main core (Moises J. A. and Martinez-Alier, V. 1978). Nova Iguaçu station presented the second highest passenger volume after the main station D. Pedro II in the Core (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.).

The Federal Railway Company serves over ninety stations in the Metropolitan Region, of which 55 are located in the suburbs of Rio de Janeiro (Moises J. A. and Stolkce V. , 1987 and Prefeitura da Cidade do

Rio de Janeiro, PUB RIO, op. cit.), and by 1973 carried about 700 thousand passengers daily in 715 trains.

In spite of their importance to the functioning and development of the city, services have deteriorated continuously over the years. Despite a potential growth of demand for services, the total number of trains has actually declined.

As a result of many breakdowns and disruptions on the railway network, Rio de Janeiro had experienced several riots during the period between 1974 and 1976. According to Moises (1987), the riots were not a result of fare increases but a response to the frequent delays and constant breakdowns (vehicles presented electrical failures on average at each 1,250 kilometres run) and the occasional fatal accidents all of which turned every trip into a potential nightmare.

All the riots occurred early in the morning involving from 3 to 5 thousand passengers on the way to work. Any disruption of services might by delaying their arrival to work, threaten them with loss of their pay on that day and for the Sunday, or even worse result in the loss of their jobs.

One of the reasons that might have contributed for the railway's deterioration and the loss of patronage was the lack of new investment in the sector . In 1975, 87% of the Ministry of Transport budget was allocated for roads, while the remaining 13% was shared between the railway and the maritime transport. While in 1960, the railway demand was 188 million passengers (by that time Rio de Janeiro's population was 3.3 million inhabitants), in 1975 demand dropped to 106 million passengers (population figures rose to 4.8 million inhabitants), providing evidence that the system lost substantially patronage in relative terms (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.). Table II shows the distribution of demand for the period 1983 to 1988 in the Metropolitan Region of Rio de Janeiro. If figures for 1983 are compared to those from 1975, a representative recovery is observed and may be explained by both: the increase of the demand in real terms and also due to the investments that took place within the system after 1975.

TABLE II

RAILWAY SYSTEM DEMAND IN RIO DE JANEIRO METROPOLITAN REGION, 1983-1988. (x 1,000 passengers)

Year	Demand
1983	221,826
1984	266,498
1985	273,999
1986	229,095
1987	231,117
1988*	91,253

* January to June only

SOURCE: CBTU, Companhia Brasileira de Trens Urbanos, 1988.

The demand for the system has not increased significantly and the main reasons could assumed to be due to the lack of incentives and improvements in the system, the irregularity of the services (in May 1988, 14% of the scheduled trips were cancelled; if only Deodoro, Japeri and Santa Cruz subsystems are considered this figure rises to 23% of the services been cancelled), and lastly to overcrowding in the vehicles in operation. So unreliability and uncomfortable conditions seem to affect the demand for this system significantly.

III.3.4. The Fleet in Operation.

The fleet in operation is quite old (life span of vehicles in Brazil are lower than for those in developed countries, especially due to the poorer maintenance) and the the cancellation of services due to breakdowns seems to be widespread. Table III shows the fleet by size and age.

TABLE III

RAILWAY SYSTEM FLEET IN OPERATION BY SIZE AND AGE

Year	number of trains	number of vehicles
1954	96 (1)	288
1965	60 (1)	180
1977	30 (2)	120
1980	110 (2)	440
1981	30 (2)	120
TOTAL	326	1148

(1) Three vehicles-train.

(2) Four vehicles-train.

SOURCE: CBTU, Companhia Brasileira de Trens Urbanos, 1988.

III. 4- THE UNDERGROUND SYSTEM.

III. 4.1- Introduction.

An underground system operates exclusively on rights-of-way and at high speeds, providing the highest capacity currently available. When operating at headway of 2 minutes and at speeds as high as 100 Km-h, they may carry up to 70,000 passenger per hour per line in each direction (World Bank, op. cit.).

Consequently they require very sophisticated signalling and control devices in order to maintain the high speeds and a low headway. The construction of an underground system takes a long time, especially if it involves substantial excavation and also may cause substantial traffic problems in built up areas. However, once in operation rapid rail transit provides a very reliable and safe service. This system is the most inflexible among all the types of transit, so any change in the existing routing seems to be unrealistic (World Bank, op. cit.).

So the system is limited to a fixed number of routes and complete city coverage seems impractical and highly expensive. In order to recover the high investment required for constructing an underground system, there is significant pressure to maximize patronage and revenues by developing an "integrated" system (World Bank, op. cit.).

Although the first study to mention an underground system in Rio de Janeiro dates from 1922, the first proposal for its construction dates from 1947, originally from the Electricity Company- Light.

However studies for the implementation of the system in Rio de Janeiro were not carried out until the late 1960s and did not became reality until 1979, when the underground started operation in Line 1 and two years later Line 2 started operating. According to these initial studies, the underground would have a capacity of 64,000 passengers per hour per direction and would cater for 533,000 passengers per day per direction, or a total demand of 1,066,000 passengers a day.

The original project of the underground was a challenge; a 67 kilometre network was planned, attending 54 stations. It was also planned to cater for 12% of the total demand of public transport in Rio de Janeiro. Unfortunately the currently system in operation is far from reaching the original project, and operates along two tracks, a total network of only 21.4 kilometres and serves only 22 stations.

The project's initial costs were estimated at US$300 to US$400 million and by mid 1987 these costs had risen to US$2,500 million, including financing charges. Many reasons could explain why costs had run far ahead of the initial estimates, such as delays in construction either by disputes of various kinds, or by inadequate funding, leading to higher costs through higher interest charges and lower productivity and also devaluation. In terms of financial results, the fare box ratio revenue-operating cost is 0.5. The system has been partially funded by the State of Rio de Janeiro and partially from Federal funds (Allport et. al. 1990).

III.4.2- The Network Distribution.

The system operates two lines, with a total network of 21.4 kilometres. It is mainly operated within the Core area, and partially in the Immediate Periphery. According to Rio de Janeiro Underground expansion plan, 18.51 kilometres are still to be built (Metrô Rio de Janeiro, 1988). Map IV presents the Rio de Janeiro Underground network referring to 1988.

The first line, called Linha 1, links the borough of Botafogo, within the Southern Zone in the Core with the borough of Tijuca (Saens Pena Station), within the Northern Zone, also in the Core, via the Central Business District. It is 11.63 kilometres long, attending a total of 15 stations. This line operates from Mondays to Saturdays from 06.00 a.m. to 23.00 p.m. On this line the expansion plan towards the Southern Zone is 4.07 kilometres long and 4 more stations would then operate.

Line 2 and Pré-Metrô (Pré-Metrô is in fact an extension of Line 2) operate from Estácio within the Central Area, in the Core, to Inhaúma, in the Immediate Periphery, a total of 9.81 kilometres. Line 2 is 7.35 kilometres from Estácio station to Maria da Graça, with a total of 4 stations that operate, like Line 1, from Mondays to Saturdays from 06.00 a.m. to 23.00 p.m.. Pré-Metrô, operates from Maria da Graça to Inhaúma, a total of 2.46 kilometres, and has 3 stations that operate also from Mondays to Saturdays, but from 06.00 a.m. to 20.00 p.m.. Between Inhaúma and Irajá services are teamporarily disrupted. Line 2 expansion network plan is 3.83 kilometres long, towards the Core, and 2 stations are to be built, while Pré-Metrô extension network is 10.6 kilometres long towards peripheral areas, and a total of 9 more stations to be built.

MAP VI - RIO DE JANEIRO UNDERGROUND NETWORK

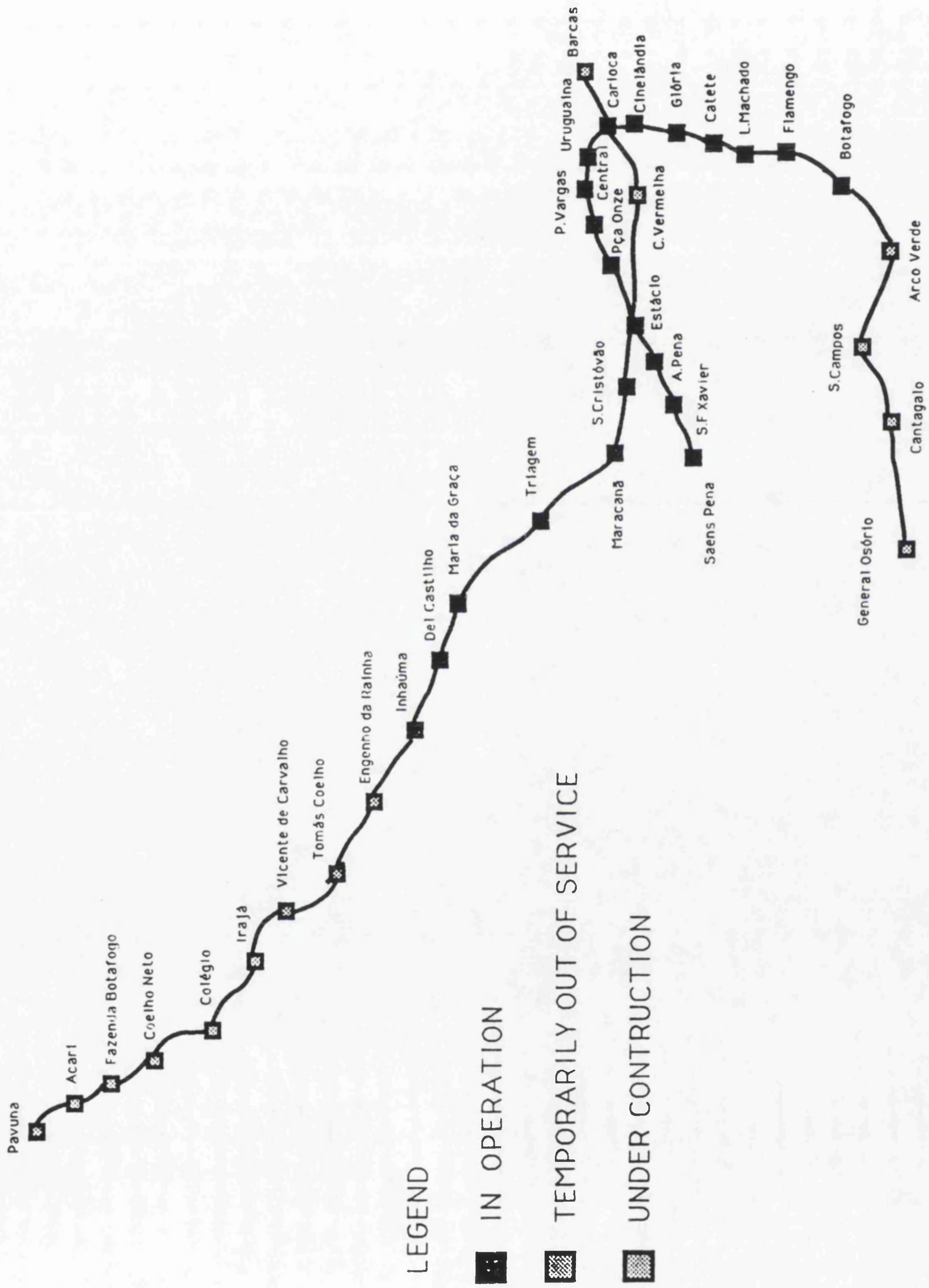


Table IV shows some figures for the underground system in Rio de Janeiro for both lines, 1 and 2. Regarding the results shown in this table, it is clear that Line 1, for operating in a higher density area has been a priority in the allocation of the resources for the completion of the project to the detriment of Line 2. This is clear when network extension, vehicles and number of stations in operation are compared. Taking Line 2 as an example, it is seen that its demand does not exceed the capacity of an ordinary bus system.

TABLE IV

RIO DE JANEIRO UNDERGROUND SYSTEM- GENERAL INFORMATION

	Line 1	Line 2	Total
Technology (1)	Full metro	Full metro Pré-metrô	-
Station spacing (Km) (1)	0.8	1.6	-
Minimum headway (Min.) (2)	3'45"	5'	-
Maximum headway (Min.) (2)	8'30"	7'	-
Cars/train (1)	6	2	-
Train capacity (1)	1,704	456-car	-
Network Extension (Km) in operation (2)	11.63	9.81	21.4
Number of Stations in operation (2)	15	7	22
Vehicles in Operation (2)	102	24	126

	Line 1	Line 2	Total
Technology[1]	Full metro	Full metro Pré-metrô	-
Trains in Operation [2] at peak	14	6	20
off peak	9	5	14
Minimum Trip Length (in Min.)	50	21	-
Operational Speed(Km-H)	30.6	48.1	-
Maximum Speed (Km-H)	77.0	70.0	-

SOURCE: (1)- Transport and Road Research Laboratory, by R.J.Allport and J.M.Thomson Halcrow and Associates, 1990.

(2) Rio de Janeiro 1988 Annual Report- Metrô Rio de Janeiro, 1988.

III.4.3- The Demand.

The system has not been able to cater for a more representative demand and still suffers fierce competition from the bus mode. If Line 1 is taken as an example; it runs under the principal avenue in Rio de Janeiro, Presidente Vargas Avenue in competition with up to 700 buses per hour per direction on the road itself, although it appears to have captured at least half the public transport traffic in this corridor (Allport et al., op. cit.). Within this corridor no fewer than 89 bus routes operate (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.)

The lack of resources to continue the underground construction and to improve the network already in operation has caused the system to deteriorate significantly in the last three years. Patronage switched to other modes, leading to a decline in the daily demand. It is estimated that at present the system has a daily demand of only 340 thousand passengers (Allport et al., op. cit.).

In October 1990, the system transported 6,6 million passengers during 27 days of operation, achieving a daily average demand of only 245,000 passengers (Rio de Janeiro Underground Monthly Report, October 1990). Table V shows the annual demand for the period from 1983 to 1988, for Lines 1 and 2, including Pré-Metrô for 1988 figures.

TABLE V

RIO DE JANEIRO UNDERGROUND DEMAND- 1983-1988

(x 1.000 passengers)

Year	Line 1	Line 2	Total
1983	112,095	5,845	117,940
1984	105,042	6,576	111,618
1985	91,098	6,043	97,141
1986	98,572	6,415	105,000
1987	88,811	6,011	94,800
1988	76,027	6,824	82,860

SOURCE: Rio de Janeiro Underground 1988 Annual Report.

If Table V is analysed it becomes evident that since 1986 the system demand is experiencing a slight decrease. One explanation for this recessive trend in demand after the transition 1986-87 according to the Rio de Janeiro Underground October 1990- Monthly Report is due to the fare policies implemented in April 1987 which raised the underground single fare to levels higher than those of the bus single fare. So before this policy implementation the underground attracted users along corridors where both modes operated simultaneously. Ever since this new policy was implemented these users have switched for the bus.

III.4.4- The Integration with other Systems.

Some of the integration measures initially planned were partially implemented such as integrated fares with some bus routes. Some of these routes were acting as feeder routes but were running very precariously. Competing bus routes were not removed. However, in 1981 some bus routes were introduced to assist in the integration of the system (fare and physically), and were initially operated by the Public Operator and later also operated by private ones.

Other types of inter modal integration (fare and physical integration) such as parking facilities allowing the use of the private car and the underground, underground with boat, and finally underground with train were also introduced. But in 1985 integrated fares accounted for only 7.4% of the underground total revenues. This total of integrated fares were shared by the bus (82.3%), the car (13.0%), the boat (4.3%) and finally by the train (0.4%) (Rio de Janeiro Underground Annual Report, 1988).

According to Rio de Janeiro Underground 1988 Annual Report, only 2.1% of the underground total passengers used some kind of integration with other systems in that year. The integration with the bus system accounted for 67.5% of this total, while the car integrated passengers were 21.3%, boat system passengers 8.7% and the train users only 2.5%.

In 1988 there were only 22 bus routes integrated with the underground system in 14 stations at Line 1 and in 3 stations at Line 2 and Pré-Metrô, from which six were operated by the Public operator and the others by private ones. Map V presents the stations integrated to the bus system.

The integration with the bus system did not seem to keep a steady demand during the period from 1983 to 1988 as shown in Table VI, when the annual demand had dropped deeply from 10.0 million to 1.2 million passengers.

This fall in the demand may be explained by the decrease and cancellation of many routes that were previously integrated with the system and also the poor reliability of the ones that still remained integrated.

TABLE VI

UNDERGROUND PASSENGERS INTEGRATED WITH THE BUS SYSTEM- 1983-1988

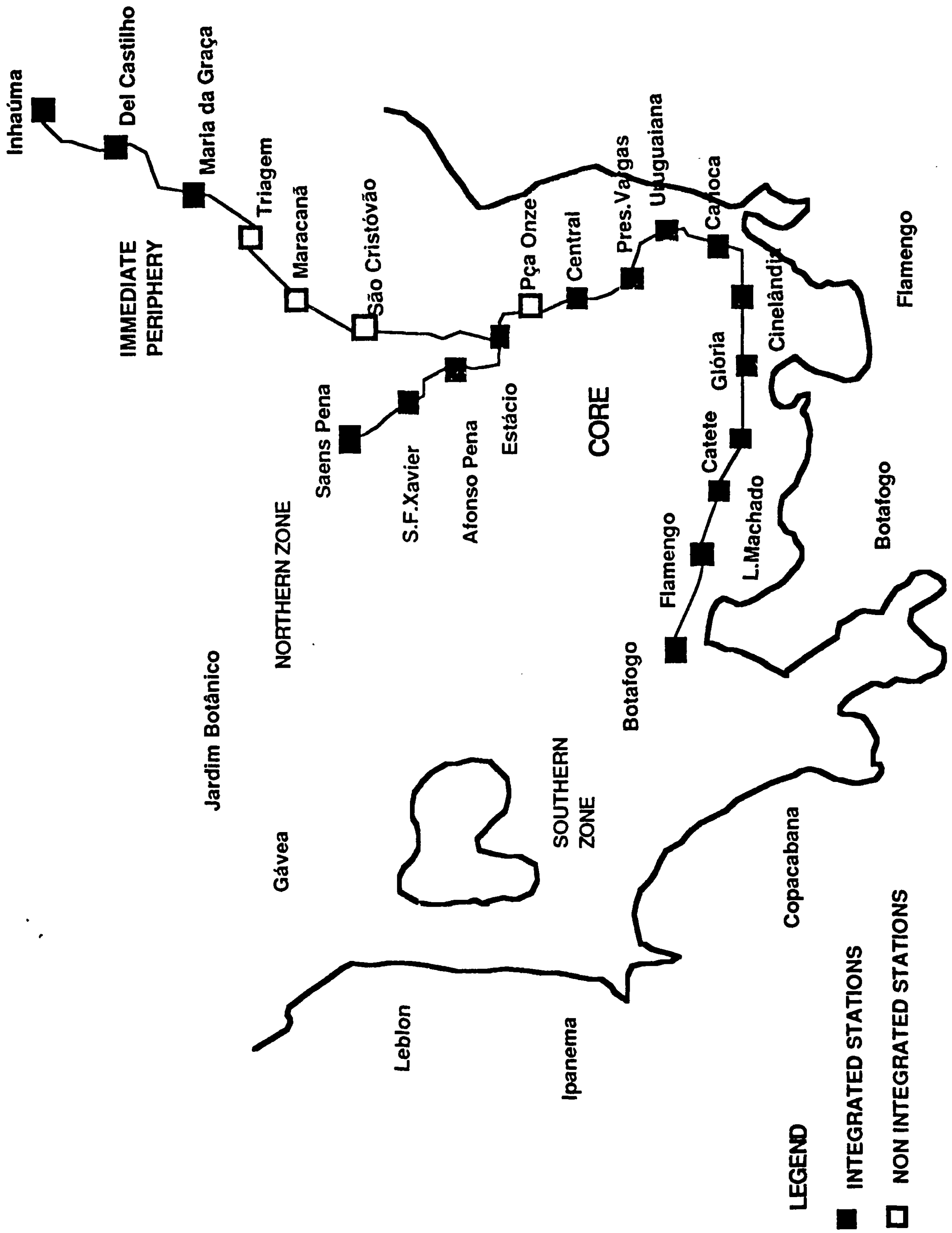
Year	Number of Passengers (in million)
1983	10.0
1984	8.8
1985	5.9
1986	4.1
1987	1.5
1988	1.2

SOURCE: Rio de Janeiro 1988 Annual Report- Metrô Rio de Janeiro.

The integration of the private transport users and the system occurs in four stations, 2 in Line 1, 1 in the junction between Lines 1 and 2, and a last one in Line 2, where parking facilities are provided. Of these four stations, two of them had parking facilities temporarily closed for the extension of the network currently under construction.

The integration of the train and the underground systems started regular operation in July 1988 but only in the Leopoldina Subsystem. In November 1988 the integration was also extend to the Auxiliary Subsystem passengers. The physical integration occurs at the following train and underground stations in each of the two systems: D.Pedro II-Central; São Cristóvão- São Cristóvão and Triagem-Triagem.

MAP VII - INTEGRATED STATIONS TO THE BUS SYSTEM



The integration between boat and underground passengers occurs at Carioca station in Line 1, catering for passengers from the Metropolitan Region that use the boat link from Niterói and also from Paquetá and Goverandor Islands in Rio de Janeiro. However a 10 to 15 minute walk is necessary between the port and underground station.

III.4.5- The Fare System.

There are several types of fares, from singles to integrated fares with other modes, such as bus, train and boat. Table VII presents all the fare categories and types and their respective values in the Brazilian currency (Cruzados) referring to December 1988.

In real terms, the value of a single fare in December 1988 was 117% higher than at the time of the beginning of the underground operation in March 1979 (Rio de Janeiro Underground Annual Report, op. cit.). It was also stated that the 1987 fare policies have raised the underground single fare to higher values than the equivalent fare on the bus and it has remained higher ever since. This fare policy may also have affected the loss of patronage towards the bus system.

TABLE VII

UNDERGROUND FARE CATEGORIES AND VALUES- (December 1988)

Type	Value in Cruzados- CZ$
NON INTEGRATED ONES	
Single	125.00
Return	225.00
Multiple (12 journeys)	1,250.00
Monthly*	3,750.00
INTEGRATED ONES	
Underground-Bus (single)	210.00
Underground-Bus (return)	380.00
Underground-Boat (single)	200.00
Underground-Train (single)	135.00
Underground-Train (return)	250.00

SOURCE: Rio de Janeiro Underground 1988 Annual Report.

* The monthly ticket does not allow an infinite number of journeys, but only two journeys a day for the whole month, which gives a 36% discount for those who use the pass regularly and totally.

III.4.6- The System Evaluation.

How can an investment of such a magnitude that was the implementation of the underground system in Rio de Janeiro be assessed? Did the system bring any benefits to the city as a whole? If so, which ones and to whom?

The major benefits resulting from the Rio de Janeiro underground implementation , as in many other cities in the developing world, were mainly accrued to higher income groups, who are the ones who can afford to use the system, although all passengers in the city have benefited from the underground to some extent. For example, bus users in terms of reduced overcrowding, lower waiting time and somewhat faster in-vehicle journeys (Allport et. al., op. cit.).

These higher income groups have also experienced some indirect benefits from the underground construction, as some land values and property prices along the underground influence area have increased significantly.

In terms of traffic congestion, the underground did not seem to have reduced it significantly. Most of its passengers were captured from the buses, but the reduction in bus traffic was not proportional and represented only a small part of the total traffic, and the traffic congestion relief is short-lived because private traffic grows rapidly to utilise the released road capacity. There has been little shift from car usage, although there was some evidence of reduced and more acceptable bus loading, especially along corridors where bus and underground still operate simultaneously and competitively (Allport et. al., op. cit.).

Any assessment of the underground system in Rio de Janeiro has to consider the fact that the system has not been totally completed, and this must to some extent affect its current performance. So when figures for the present demand is far below the expected one, it may be considered that the disruption of the system in Botafogo towards the Southern Zone in Line 1 and in Inhaúma, towards peripheral areas in Line 2, still obliges the use of the bus system beyond these points. This does not encourage the use of the system. Moreover the bus seems more attractive from the financial point of view as a single fare on a bus is lower than on the underground.

III.5 - THE BUS SYSTEM.

III.5.1- Introduction.

Although the bus is the main mode of transportation in Brazil; there are in the whole country 3,000 operators and 90,000 vehicles operating 27,000 routes. Services are still quite rudimentary, firstly because except in larger cities, they are provided mainly by small operators and secondly because operating costs are fairly high if compared to general users' affordability and the non existence of any kind of subsidies, and finally because the vehicles used for operation are technologically out of date, and operators do not seem to be interested in investing in vehicles of higher technology (Branco A. and Kassab, D. 1983).

In Rio de Janeiro the bus is the most representative mode of transportation, with a average daily demand of approximately 4.5 million passengers. In many cities throughout the world, buses when using several lanes along one same corridor and with no rights of way, may carry from 25,000 up to 30,000 passengers per hour in one direction.

Under such circumstances operating speeds may be as low as 12 kilometres per hour (World Bank, op. cit.).

However reserved bus lanes may enhance bus operating speeds up to 18 Km-h, consequently passenger volumes may rise up to 15,000-20,000 passengers per hour per lane, respectively for standard vehicles and larger buses. In São Paulo bus ways even without completely exclusive conditions, regularly carry more than 27,000 passengers per hour in single lanes, achieving operating speeds of 19 Km-h (World Bank, op. Cit.).

In Rio de Janeiro the bus network was mainly developed during the sixties by market law and also as a replacement for the tramway system and the micro buses called "lotação". These micro buses, run privately by too many small operators, were the main option for several years in Rio de Janeiro. Their fleet reached approximately 5,000 vehicles, which resulted in a chaos and led the city authorities to abolish them in 1962. Due to the importance of the bus in Rio de Janeiro, the main focus of research will be on this mode of transportation.

In 1984 the bus share attained its minimum level for the period from 1981 to 1987 of 75.94% among the other modes of public transport, while the maximum figure for the decade 82.1% was achieved in 1981. Figures for 1987 were around 80%, as shown in Table VIII. This presents the relative journeys modal split in Rio de Janeiro for the period 1981-87.

TABLE VIII

RELATIVE JOURNEYS MODAL SPLIT IN RIO DE JANEIRO- 1981-1987

	Year						
Mode	1981	1982	1983	1984	1985	1986	1987
Bus	82.11	78.31	76.66	75.94	77.28	81.33	80.16
Railway	12.17	12.50	13.33	14.98	14.40	11.08	11.41
Underground	2.29	5.90	6.82	6.08	5.10	5.08	5.60
Boat	3.44	3.29	3.19	2.99	3.22	2.51	2.83
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: Superintendência Municipal de Transporte Urbano- SMTU
Companhia de Transportes Coletivos- CTC.

From Table VIII the importance of the bus mode in the public transport system in the city of Rio de Janeiro is clearly seen.

The Transport Municipal Secretary is responsible for the coordination of the system. This position was recently created by decree by the Municipal Law Number 881 from 11-07-1986.

The system is run privately by 33 enterprises and one state company, CTC-RJ, which operates bus routes not only in Rio de Janeiro but also in other municipalities throughout the State of Rio de Janeiro as well as a remaining tramway service between the borough of Santa Teresa and the CBD, in the city of Rio de Janeiro.

Current private operators originated from previously smaller entrepreneurial companies. In 1963 the Government encouraged that small bus operators merge to form bigger enterprises. In 1967 a minimum operator fleet size of 60 vehicles was established. In 1972 there were 121 private operators in Rio de Janeiro. In 1981 the minimum fleet size was determined to be 120 vehicles per operator. This measure aimed at providing a more systematic service by concentrating fleet and routes. At present, enterprises in Rio de Janeiro range from the minimum size of 120 to 346 vehicles.

The public operator CTC-RJ was founded in 1962 by the State Government of Guanabara to take over the Light Company assets and then to operate the trolley bus and tramway systems. In 1969 the trolley buses started being adapted to use the internal combustion engine, until 1972 when that system was completely out of operation. Today the share between private and public operators is 96.1% and 3.8% respectively, as shown in Table IX.

TABLE IX

SHARE BETWEEN PRIVATE AND PUBLIC BUS OPERATORS (1981-1987)

	Year						
OPERATORS	1981	1982	1983	1984	1985	1986	1987
Private	92.02	92.93	93.35	94.33	94.20	94.70	96.09
CTC-RJ	7.37	6.63	6.32	5.42	5.64	5.16	3.77
Special Bus Service	.62	.44	.33	.25	.16	.14	.15
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: Secretaria Municipal de Transporte Urbano- SMTU.

From Table IX it is evident that the public operators share is very small compared to the private operators and recently has lost further ground to the private market.

In November 1985, the State Government took over sixteen Private Operators and the public share went up to 25.7%. Figures in Table IX do not consider this event. In January 1988 these operators were returned to the private sector by the Government.

Concerning employment generation, the Rio de Janeiro bus industry employed 30,486 people in June 1988 (Rio de Janeiro Private Operators Trade Union, 1988) while the CTC-RJ public operator had 4,219 employees in March 1988 (CTC-RJ, 1988) including employees in Municipalities other than Rio. If private and public fleets are taken into account, the ratio between workers and vehicles was 6 and 14 employees per vehicle respectively for private and public operators.

The total fleet consists of approximately 6,000 vehicles, from which only 329 belongs to CTC-RJ.The average fleet age is approximately 3 years old (Rio de Janeiro Private Operators Trade Union, 1989) excluding the CTC-RJ fleet which is approximately 7 years old (CTC-RJ, 1988).

The Rio de Janeiro bus system operates approximately 400 routes. In general services run from very early in the morning to very late in the evening, and there are 95 routes that also operate night services regularly.

From these figures, CTC-RJ operates only 25 routes in Rio de Janeiro and during the last four years has cancelled operation in 14 other routes, of which five were integrated routes with the underground system. They also operate three routes between Rio de Janeiro and Niterói not included in this analyses, as they are inter municipal routes. CTC-RJ total bus network extension in Rio de Janeiro is 655 kilometres.

Table X presents some information regarding to fleet size and fleet average age, number of routes operated, and finally the number of employees for 33 out of the 34 bus operators in Rio de Janeiro, including the public operator CTC-RJ.

TABLE X

OPERATORS CHARACTERISTICS

Operator	Fleet (1)		Routes (2)	Network(3)	Employees(4)
	Size	Age*	Operated	(km)	
Novacap	125	1.79	5	157	636
Campo Grande	143	2.59	7	262	769
Verdun	324	1.63	10	236	2114
Viação Bangu	225	3.18	7	318	1245
CTC-RJ (5)	329	7.70	25	655	1398
Oriental	223	3.83	17	595	1187
Caprichosa	127	2.99	9	257	671
Três Amigos	162	2.69	7	210	896
N. S. Lourdes	142	3.21	8	286	1069
Santa Maria	133	2.91	11	257	785
Auto Diesel	346	2.74	16	822	2137

Operator	Fleet (1)		Routes (2)	Network(3)	Employees(4)
	Size	Age*	Operated	(km)	
Redentor	336	4.27	28	773	1886
Paraense	126	5.29	7	153	646
Estrela Azul	124	3.84	5	169	731
Paranapuan	201	3.74	12	427	1115
São Silvestre	262	3.57	15	330	1370
Real	273	4.16	15	417	1647
America	130	2.74	9	236	724
Rubanil	123	1.51	6	260	698
M. Candelária	158	2.13	6	188	937
Amigos Unidos	210	4.29	17	345	1123
Viação Acari	120	1.01	5	86	689
A. Matias	120	1.26	5	98	644
Viação Tijuca	125	1.39	13	211	739
Vila Isabel	156	4.29	6	229	849
Viação Jabour	169	1.83	23	76	991
Braso Lisboa	135	1.31	7	262	871
Pégaso	143	1.78	8	820	423
Estrela	125	1.30	6	167	756
Mosa	178	3.14	10	241	1026
Santa Sofia	195	2.58	31	-	1033
Ideal	120	4.05	8	242	662
Pavunense	120	1.78	8	113	633
Total	6.060	2.86	386	10,118	33,897

SOURCES: (1) Private Operators Trade Union, November 1989.

(2) Private Operators Trade Union, Operational Report, January-October 1988, 1988.

(3) CET, Companhia de Engenharia de Tráfego- network extension is not available for all routes so data is misleading.

(4) Private Operators Trade Union, November 1988.

(5) CTC-RJ, Annual Operational Report, December 1988, for the data for CTC-RJ.

* average value in years.

With the relationship between fleet age and size it is observed that most of the newer fleets are operated by enterprises with smaller number of vehicles. The only exceptions are Verdun with 324 vehicles, on average 1.63 years old, (new and big fleet) as well as Ideal and Paraense, that have fleets of 120 and 125 vehicles, 4.05 and 5.29 years old respectively (small and older fleet) are the only exceptions. On average the fleets in operation are quite new, except for that of the Public Operator, which operates vehicles older than the permitted age limit (namely seven years).

III.5.2- The Network Distribution.

Is land use a determinant of public transport provision? The specific and temporal patterns of travel demand that are likely to occur in a given urban area are a function of the properties of the area in concern, the activities that take place in these areas, and the availability of transport facilities.

Travel demand patterns can be classified according to land use in five broad categories (Hutchinson, 1974);

. Type 1- Radial type travel along corridors on the central business district.

. Type 2- Circumferential type travel between activities located in the suburbs of cities.

. Type 3- Travel within residential areas where this type of travel might be between local area activities or travel at the beginning or completion of a longer trip within an urban area.

. Type 4- Travel within the central business district where this travel might be between activities within the central area or to and from terminals of regional transport facilities focussed on the central area.

. Type 5- Travel to and from major activity concentrations not located within the central area such as Airports, Universities, and recreational areas.

In the specific case of Rio de Janeiro, it can be seen that the most representative trip patterns are types 1 and 3, and to some extent type 2. Basically three link types may be identified in Rio de Janeiro according to the five categories defined above; radial, diametrical and local ones. The trip patterns are result of land use, taking into account mainly housing and labour market locations and the available transport.

As stated in Chapter II, the Core concentrates 60% of the labour market with peripheral areas the remaining 40%. As a result of this distribution, most of the trips generated have the Core as their main destination or occur within the proper Core.

In contrast to trends observed in developed countries, where a stabilization or even a low rates of growth of centrally focussed travel demands are observed, Rio de Janeiro still experiences a steady growth of this travel demand type. As long as this land use pattern continues, travel type 1 will remain the most representative among the five categories considered. It is not by chance that most of the investment has been occurring in Rio de Janeiro, the best example being the Underground system construction which has taken place mainly within the Core area.

The Rio de Janeiro bus system network is following the main patterns of travel according to land use. There are five route types in Rio de Janeiro according to the area where services are provided. They are; North Local, North Radial, Diametrical, South Local and South Radial.

1- North Local routes;

This route type runs mainly within the Immediate and Intermediate Peripheries in an area that is also known as Zona Norte (Northern Zone). There are 211 routes of this type of which 44 run night services. This route type is the most representative among the five, covering an area of approximately 1,100 square kilometres, with a population of 4,027,760 inhabitants.

2- North Radial routes;

This route type links the Central Area (within the Core) to boroughs located in the Core itself and Immediate and Intermediate Peripheries which are all towards the Northern and Suburban Zones. There are 85 routes of this type and it is the second most representative one, leading the northern routes to a total of 296 bus routes. There are 25 North radial routes that provide night services.

3- Diametrical routes;

These routes operates between the Southern Area (within the Core), Northern Area (partially within the Core and partially within Immediate Periphery) via Central Area within the Core. As the Core and especially, the Central Area and Southern Zone concentrate a significant percentage of the labour market, it is plausible for so many links to operate within these boundaries. There are at total of 33 routes of this type and 10 of them operate night buses.

4- South Local;

This route type operates exclusively within the Core in its southern part, Southern Area. There are 23 south local routes of which 9 run night buses, that serve an area of 33.5 square kilometres and a population of 712,364 inhabitants. This area has the highest car ownership level; 258 thousand vehicles or an average of 1 car for every 2.75 inhabitants.

5- South Radial routes;

These routes link the Southern Area and the Central Core. There are 25 routes of this type, leading to 48 routes of the southern type. Only 8 routes run night services.

It is interesting to note that the Core is served by all five route types; Immediate Periphery by three (North Local, North Radial and Diametrical) while Intermediate Periphery only by two types, North Local and Radial routes.

There is another distinction between the routes that are circular and non circular. The first type, origin and destination coincide in one point, while in the second type origin differs from destination. Most of the circular routes are South Local ones.

III.5.3- The Fare System;

The fares are established according to the route operating costs. These are mainly labour costs, fuel, vehicles depreciation and their future replacement (9.7% of the fare is allocated for this purpose). The capital return accounts for 7.3% of the fare (Urban Transport Municipal Superintendency- SMTU) The route demand is also considered in a way that the costs are shared equally by all route users. In other words every route has its specific costs per trip, which are multiplied by the unitary fare level, considering the trip length and its average daily demand.

Demand figures are provided by the operators to Public authorities, who determine the fare levels, which may lead to fraud. It seems very difficult, if not impossible to check the accuracy of these numbers. It is argued that operators usually tend to conceal the real demand in order to push fare levels up. Amongst the twelve items in the costings, 40% relates to labour; 30% to fuel and lubricants; maintenance to 5.3%; administrative charges to 1.3%; 0.5% to tax and insurance (SMTU, op. cit.).

There are ten different fare categories which are shown in Table XI with their respective values, from September to November 1989. Fares were rising on a monthly basis as a result of the high inflation rates.

TABLE XI

FARE CATEGORIES (in Cruzados- CZ$)

Categories	September	October	November	Routes (%)
I	0.40	0.55	0.70	8
II	0.52	0.71	0.90	9
III	0.65	0.88	1.10	65
IV	0.90	1.25	1.60	5
V	1.05	1.43	1.80	4
VI	1.20	1.65	2.10	3
VII	1.30	1.77	2.30	2
VIII	1.45	2.00	2.50	2
IX	2.10	2.90	3.60	1
X	2.40	3.30	4.20	1

SOURCE: Sindicato das Empresas de Transporte de Passageiros do Município do Rio de Janeiro, Fare Report, November 1989.

Figures for Table XI show that the highest fare corresponds to six times the value of the lowest fare. From all routes operated privately, 65% charge fare category III, being the most representative fare in Rio de Janeiro. The first two categories are usually charged for routes of very short distance, mainly feeder routes for the bus system itself or the train.

Fares seem to be a very important issue for discussion. From the way they are structured and the main profile of trip patterns, it can be seen that although the network covers an extensive area, it is not always possible to travel from one point to another without an interchange. Interchanging results in an extra fare to be paid. If the fact that the Government has established a maximum the workers should spend in transport, that is no more than 6% of their monthly earnings is considered along with the income levels, it is very difficult if not impossible to keep the transport costs under this ideal limit.

Some estimates of transport costs in Rio de Janeiro carried out in May 1988 have considered a rate of 50 trips (per individual) a month in fare category III. For those earning up to 1 MW transport costs would then represent 16.07% of their income, while for those earning 2 MW, this figure would drop to 8.03%. Only those earning more than 2 MW would fall within the 6% level of expenditure. However these figures are not precise because they did not considered the fact that a significant percentage of the population in low income categories, usually pay fares of upper categories and also are likely to make interchanges. Peripheral inhabitants may pay up to 23% of their earnings (Branco A. and Kassab D., op. cit.). There is no comprehensive fare integration among different routes or operators. As stated in the previous section there is only a very precarious fare integration system on a few routes in the underground.

Since the early sixties, fare policies have followed four major directions at different levels of government action (Orrico , R. D, 1988);

1- Fares have been raised regularly, often in excess of the observed production cost indices, so that high profits can be guaranteed in the private sector.

2- Direct Federal Government action has been taken to reduce fuel consumption in response to rising fuel prices. This action included the development and application of new specifications for motors and new operating techniques, particularly bus lanes.

3- Fare calculation sheet studies have been introduced, with a view of improving and adopting productivity indices.

4- Limited use has been made of subsidies directly to users, especially cross subsidies for users of the same public transport.

Parallel to these policies at national level, some measurements were proposed or in some cases adopted in order to tackle the transport cost burden, especially for those less well off. Many attempts have been made to mitigate problems resulting from high fares in public transport. Some fares were lowered on certain routes considered to be of social importance and before the morning peak, e.g. early in the morning, from 4 a.m. to 6 a.m. Students in most Brazilian cities pay half fare, but not in Rio de Janeiro. Recently the elderly have been granted free travel in Rio de Janeiro, as long they produce evidence that they are over 65 years old. The cost of the cross subsidy used in almost all these cases was absorbed by a slight increase in the basic fare (Orrico, op. cit.).

Two measures were proposed at national level; the Travel Voucher and the Metropolitan Transport Fund (MTP) (Orrico, R. D., op.cit.).

The Travel voucher is a special benefit that only those with a formal employment could make use of, and guarantees that their monthly costs would not exceed 6% of their earnings. The difference would be paid by the employers, who in turn would be entitled to certain tax benefits (Orrico, R. D., op.cit.).

The MTP was inspired by the "Versement-Transport" widely used in French urban areas. Any company with more than ten employees that did not provide free transport to and from work would be required to contribute 1% of its payroll. The MTP would also be complemented by resources from already existing taxes on fuel and by contributions from local authorities. This proposal was never adopted (Orrico, R. D., op. cit.).

The Travel Voucher was created by decree in December 1985. Adopting the travel voucher was optional, and the employer could choose whether to use it or not in the light of possible compensations and incentives. The implementation depended on the regulation of local governmental bodies.The implementation itself faced so many problems, that by May 1987 it had been adopted in only 13 out of 26 major urban areas in Brazil (Orrico, R. D., op.cit.).

In the case of Rio de Janeiro, for instance, these regulations were not completed until one and a half years after the initial voucher creation.In July 1988, 500,000 passengers benefited from the travel voucher in Rio de Janeiro, a figure far below the monthly forecast of 1,500,000 travel voucher passengers. If the daily demand for public transport in Rio de Janeiro is considered, 15.6% of the total passengers are travel voucher holders which is very close to the National average of 16% (Orrico, R. D., op.cit.).

A criticism of the Travel Voucher scheme is that only those with formal employment could benefit, excluding those employed within the informal sector. According to CBTU (Companhia Brasileira de Trens Urbanos-Brazilian Company for Urban Trains), half of their passengers have no formal employment relationship, and the company received only 750 thousand vouchers per month, accounting for only 3% of their total network journeys. According to the National Household Research (Chapter II), 35% of those engaged within non agricultural activities in the country had no formal relationship with their employers.

Other limitations of the voucher scheme are that it covers only commuting trips to and from work or a total of two journeys per day, excluding any other eventual trips with purposes other than work.

III.6- PARATRANSIT.

Paratransit is the term applied to small passenger transport vehicles operating informally on a fare-paying basis. Often paratransit is a valuable supplement or alternative to regular bus transit services. Paratransit may be particularly advantageous in areas where demand is not sufficient to support the use of large buses at desirable frequencies. Often the small vehicles mostly used are the only form of transport able to penetrate the narrow streets in older parts of the town or in squatter settlements. (World Bank, op. cit.).

Given the informal nature of the operation of a paratransit, no data is available concerning this type of transport in Rio de Janeiro. However, at least three different types of paratransits operate there: converted vans (with a capacity from 8 to 12 passengers) in hilly squatter settlements carry dwellers up hill from the bottom of the settlement; buses known as "ghost" buses operate between peripheral areas and the core during peak periods. They charge lower fares than the regular bus services to attract users; and finally shared taxis, that are regular taxis, whose drivers collect passengers along Brazil Avenue on their way to work in the core. The amount charged may cover their costs with petrol to reach the core.

III.7- PRIVATE TRANSPORT.

In Brazil the number of private vehicles per 1,000 inhabitants increased twofold from 1971 to 1981 (Dimitriou, H. 1990). In Rio de Janeiro the private car population was estimated in 1989 to be 1,340,000 vehicles (PITMETRO, 1977). While the average annual per capita income grew 5.1 percent, car ownership increased at an annual rate of about 10 percent (World Bank, 1986).

In the Metropolitan Region of Rio de Janeiro the private car corresponds to 16.5% of the total vehicular trips or approximately 2 million trips per day of which 1.1 million are within the city of Rio de Janeiro. The city car population was approximately half a million vehicles in 1975 (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.).

If these estimates are accurate, Rio de Janeiro had experienced an almost threefold increase in its private vehicle numbers in the past fifteen years.

The distribution of this private ownership among the three areas in study follows a very uneven pattern which is shown in Table XII.

TABLE XII

PRIVATE CAR OWNERSHIP SPATIAL DISTRIBUTION- 1989 ESTIMATES FIGURES

Area	Figures (x 1,000)	%
Core	644,2	48
Immediate Periphery	582,5	43
Intermediate Periphery	113,7	9
Total	1,340,4	100

SOURCE: PITMETRO, Plano Integrado de Transportes, Relatório Final, Rio de Janeiro, 1977.

From the figures presented in Table XII it is worth noting how concentrated car ownership is in the Core, where within the Southern

Zone no less than 20% of the total number of private cars in Rio de Janeiro is found. The borough of Copacabana within the Southern Zone generates 10% of the trips by private transport in the Metropolitan Region (Prefeitura da Cidade do Rio de Janeiro, PUB RIO, op. cit.).

In 1975 the relationship between population per vehicle ranged from 5.58 people for vehicle within the wealth Administrative Region of Copacabana (PITMETRO, 1977) to 27,22 people per vehicle in the far and poor suburban Administrative Region of Santa Cruz, reinforcing how wealth and poverty are segregated within Rio de Janeiro. Recent figures give evidence that the car may account for almost 20% of the total vehicular trips generated in Rio considering private and public modes.

III.8- CONCLUSION.

It is evident that public transport played a decisive role in the Rio de Janeiro urbanization process.

From this chapter it becomes clear how important transport has been in shaping Rio de Janeiro, and segregating population socially and economically.

While the train has developed the city towards the suburbs and periphery, the tramway developed towards the sea side and the Core. This enabled the dichotomy between the Core and Periphery which initially emerged last century, to be perpetuated during this century. This dichotomy has also reinforced the dependency of peripheral areas on the Core in terms of jobs, facilities and so on. On the transport side, this dependency is reflected in the population's pattern of travel. The most representative travel type is that of trips of the so called radial type, having the Core as the main destination.

The concentration of the labour market in the Core keeps reinforcing the need for new investment in the area to tackle the ever increasing demand for public transport. Also this is the demand that can afford new and higher cost services.

From all modes of public transport, the bus seemed to be the one that catered for the highest demand, mainly because of the low investment required and the mobility the technology provides. Other technologies such as underground requires higher investment, and considerable amount of time to be entirely completed. As a result, the bus system still competes vigorously with the underground especially along corridors of high demand. The lack of a fare integration system reinforces the demand for the bus mode, as well as the lower fares of the bus in comparison to the underground.

Although the private car accounts for almost 20% of the whole vehicular trips in Rio de Janeiro, car ownership is the privilege of a minority, which is mainly concentrated within the Core area, where public transport is better provided. Peripheral dwellers are the most dependent on the public transport and their access to private mode is scarce.

It would be appropriate for different transport modes not to compete amongst themselves if they were integrated physically and economically. Most users and non users would certainly benefit from this.

In respect of the cost of transport, it is known that expenditures on transport is a product of where people live and work and their income. The way the city is structured affects those less well off as they tend to live in peripheral areas but remain working within the core and consequently commute long distances, at higher costs. The attempts to ease the problem, such as the travel voucher scheme have not been totally successful, as only those employed within the formal market were eligible for it.

Therefore, transport seems to be reinforcing the social and spatial segregation of the population. Better paid jobs are mostly located within the Core, and for access to these the population is forced to undertake long and costly trips to and from work. This vicious circle looks impossible to break as long as land use patterns keep the concentration of income, welfare and labour market within the core and the dichotomy between core and periphery remains.

For the analysis of how services perform, two different perspectives were considered; from the supply side or operators and from the demand side, represented by the users of the system. While the first one tends to maximise their profits, the latter demand good services, high accessibility, lower costs. Different attributes may influence users upon their decision making process. In Chapter IV some performance measures are defined and tested among the operators, analysing the system from the supply side, while Chapter V, presents the results of the fieldwork, analysing the system from the demand side.

CHAPTER IV- TRANSPORT SYSTEM EVALUATION.

IV.1- INTRODUCTION.

If transport is a constitutional right and a State duty to provide it, it may be asked to what extent this right is being fulfilled and if all citizens are being provided with an equitable service.

However, merely living in a city does not ensure access to either employment or to services, although there are strong links between employment, income and the availability of transportation and the access to the use of it (Pederson, E.O. 1980).

Transport services are widespread. However services are neither provided nor consumed uniformly. In large cities transit caters for a variety of trip purposes and income groups (Fielding, G. 1987).

The distribution of access (time-distance to facilities) is unequal, both geographically and socially. People live at varying distances from facilities and differ in their ability to overcome this by means of transport (Boer, E. 1986). However, the first to gain access to new transport technologies tend to be the wealthy and the most powerful (Adams, J., 1981).

Unequal access to transport is indicated by disparities in use and ownership of transport means. Availability and utility are the essential qualities; who can utilize specific means of transport, when and for what purposes (Hillman M. et. al., 1973,76).

In addition to this demand for public transport will depend not only on factors within the control of those providing the services (operators) such as fares and frequencies, but also on factors beyond their control such as income levels, car ownership (Savage, I. 1985).

Some questions can be raised as a starting point for discussion such as to what extent is land use a determinant of public transport provision or if the quantity and quality of services are affected by income levels.

Given the rapid growth of the cities, especially in developing countries, and the frequent location of low-income areas on the fringes of such settlements, low income trip makers may have to travel much greater distances than they would wish. For those with no financial constraints, a mix of higher cost and higher quality modes offering greater comfort and privacy is often available and it is affordable (White, P. 1990). In addition to this, as the journey length increases the frequency at which people undertake trips is likely to decrease (Adams, J. op. cit.).

The extension of an urban area has a substantial influence on both the standard and the costs of public transport system.

The main hypothesis raised in this research is whether or not imbalances in the provision of bus transport are significant among different areas in Rio de Janeiro, considering differences in population income and welfare, and their distribution in urban space. Provision here is being considered not only in terms of how demand is being matched by supply but also how satisfactorily one is being matched by the other. So provision is considered from a quantitative perspective and from a qualitative one.

Other questions can be raised, such as what would be the most important expectations of a public transport user and if these expectations would differ according to their income?

The importance in analysing imbalances on the bus service provision relies on the role transport plays on individuals' life; in enabling them access to facilities and productive activities which consequently enhance their welfare and well being. If provision of services is lacking, poor or unbalanced for some individuals or restricted to some areas, their accessibility, welfare and right of movement will be significantly disrupted.

Does the system ownership have something to do with the quality of services provided? In Rio de Janeiro, the provision of the bus service is being mainly determined by the market and is mostly operated by private companies which tends to concentrate supply where demand is most concentrated. If the supplier side is analysed, the services would be probably appear to be operating perfectly as a result of being market oriented. But what about the consumer side?

How can demand and supply be balanced, if their objectives and goals are different? On the one hand public transport operators' major objectives and constraints are usually financial. The private operator expects to obtain some level of profit after covering operating costs. On the other hand consumers of public transport facing constraints such as time and money, will generally try to maximise their access to the facilities they desire to reach, and to minimise their costs (White, P. op. cit.).

It seems that priorities must be established, given a potential demand to be satisfied with a given supply.

If the research hypothesis is confirmed, what would be the recommendations to minimise imbalances in the provision of services? Would the alternatives be transport oriented or would solutions also rely on other spheres of planning, such as land use policies?

No system could offer a uniform quality of service coverage, but some minimum standards should be established concerning a socially acceptable level of provision of a service. Services should then be offered according to these set standards. In respect to public transport, some attributes related to frequency, comfort, convenience, reliability and safety are among the ones that could be considered within these minimum standards.

Many statistics are available to measure transport system performances, such as vehicles operated, total vehicle-kilometres, headway and so forth. Although these figures provide one dimension of the system performance and services provision, they are somewhat limited by not considering other aspects of service that interest potential and current users of the system, and that are often not recorded such as reliability of the service, variability in travel times and waiting times. Also it must be considered that the usefulness of a transport network depends on the density of land uses which it serves and cannot be assessed in isolation (Fielding, G. op. cit.).

In a system operated mainly by private companies such as in Rio de Janeiro, the rule is to maximise profits no matter what level of service is being provided. In this specific case it could also be said that private bus operators constitute a huge monopoly, and face no competition. They offer the services they want to, sometimes not respecting some rules laid down by local authorities. There is always a captive demand and those dependent on their services. Moreover, it is observed that within different areas of the city each operator monopolises parts of the market in spatial terms. Again, as a result of the absence of competition some areas are poorer served than those where some kind of competition does exist or where other alternatives are available.

Observed higher rates of trip generation within and towards the Core, as a result of the concentration of labour market, results in a over supply in these areas, to the detriment of peripheral areas which are poorly served.

How far can these imbalances in the provision of services go and remain acceptable? How can the differences in the provision of services within the bus system be measured and established? How can these hypotheses be tested?

The bus system is analysed from two different perspectives, taking into account two of the main factors involved in the system itself that are the operators and the users, each representing the system supply and demand. Certainly that their needs differ, and also their expectations.

According to Tomazinis (1975), the operators-supplier of the system are the most obvious groups who have a direct role and impact on the system. Their point of view therefore must always be taken into account. Essentially, they provide the basic capital for the construction of the transportation mode and for its satisfactory operation. Thus they will be found providing the network of the system, and-or rolling stock, and-or operating labour, and-or managerial and technical skills required for the operation of the system, plus repair and maintenance facilities.

The second factor that is always present in urban transportation is the direct user of the system. In fact the user of the system makes major inputs to the operation of the system and is the first one to realise the system's output. In terms of input he contributes with his time, contribution of fare, accident risks and personal efforts. In terms of output, he receives the trips completed in the system plus a level of comfort and contentment.

Depending from whose perspective the system is being evaluated, different approaches can be adopted. For the supplier of the system the measurement of quality of the system is made along the dimensions of efficiency and productivity. The more efficient and productive a system is, the better this system will be, from the point of view of the operator (supplier). For the consumer, this is not necessarily so. Productivity is concerned primarily with the relationships between total system inputs and outputs. Efficiency is related to the rate of success, a specific process in achieving a given objective.

From the operator's point of view (Tomazinis, op. cit.), the analysis of service efficiency should be able to assist him to assess or determine in absolute or relative terms the success he has had in achieving desirable objectives in five areas of concern. They are: unit costs, input of resources, relative distribution of costs, provision of service and collection of revenues. Many performance measures can be defined according to these five areas of concern.

Considering the users' perspective, it seems advisable to develop efficiency measures that indicate to the user the extent to which certain desirable objectives and preconditions have been met. Here four areas of concern are defined: cost of travel, quality of travel, reliability of service and safety and security.

To analyse the system operation and services provision from these two factors' perspective some evaluative attributes and performance measurements are defined and tested. First, at the operating supplier side in this Chapter and later at the system users' side (Chapter V).

The criteria for defining the measures to be considered in the analysis is the result of the availability of data from secondary sources. The adoption of a fieldwork aimed at completing the missing data and also to get primary information directly related to one of the second factor within the system namely the user.

IV.2- BUS SYSTEM EVALUATION.

IV.2.1- Introduction.

Measures of performance for bus services can be considered from different points of view; from the operator , the user or even the public authority. For example, the operator may wish to know how the service operated compares with the predetermined schedules; or the passenger may be more concerned with whether or not a seat is available for his journey, whereas the local authority may take a broader view and look at global measures such as passenger-kilometre or load factors.

According to Tomazinis (op. cit.), an alternative basis for classification is to categorise performance measures into efficiency and effectiveness measures. Efficiency measures are those which evaluate the quality of system management and operation and rate the process by which transit services are produced, particularly through the relationship between inputs and outputs; while effectiveness measures are used to quantify the success of services with respect to the policy objectives set for them, often related to their effectiveness in serving the public. In other words they compare service actually provided to output or objectives which were intended and they examine the character and location of service.

As an example some measures of efficiency could be cited such as running costs, vehicle utilisation, labour productivity, and energy efficiency. Most of the effectiveness measures can be classified as measures of quality of service that include accessibility, reliability, comfort, convenience and safety. Some others do measure the utilisation of the services such as passenger per vehicle, passenger-kilometre per vehicle-kilometre, revenue passenger per vehicle kilometre, seat turnover and finally some cost effectiveness measures such as operating expenditure per total passenger, operating costs per operating revenues.

At this stage some performance measurements are defined and tested among operators of the system, giving a picture from the supplier side. To build up the data set, different sources were used and for this reason not all the data was available for all operators or for all routes that they operate in Rio de Janeiro. For that reason two levels of analyses were adopted, one in a more aggregate level considering operators performance and another in a more disaggregate level on a route by route basis. All the steps adopted were important for further investigation in the field.

The data available for the initial evaluation was provided by the Private Enterprises Trade Union (Annual Operational Report, for January to October, 1988). Figures for operators performance and its respective correlation matrix is presented in Appendices II and III respectively. This report presents all the operators records by route on a monthly basis, e. g. fleet in operation, supply, trips made, distance travelled, passengers transported and revenues. From the same source other variables were available such as number of employees, total fleet number and its age. This data referring to fleet age was updated in November 1989. From the Traffic Engineering Department (CET) data relating to routes running times for peak and inter peak periods and journey distances were collected, in a survey carried out in 1984, allowing the calculation of operating speed and headway. Unfortunately this data was not available for all routes; only 198 of the almost 400 routes. At the second stage of the analyses only these 198 routes were considered.

In accordance to Martin Higginson (1989), a successful measurement of efficiency in public transport depends on the validity of two hypotheses. These are:

1- That there are differences in the efficiency of production and effectiveness of different public undertakings.

2- That these differences are capable of measurement and quantification.

In order to measure and quantify the imbalances that might occur among wealthier and poorer areas and the provision of bus services and in order to support the initial argument that these imbalances are significant, some performance measurements are established and defined. So it is being assumed that differences occur (Hypothesis 1) and then they are able to be quantified (Hypothesis 2).

IV.2.2- Performance Measurements.

IV.2.1- Introduction.

Next, some performance measurements are defined in accordance with three main categories: Input-Output, Revenues and Capacity Measurements. The measures were established taking into account the available data from secondary sources.

IV.2.2.2- Input-Output Measures.

All the first three measures considered here are measures of utilisation of service, while the fourth relates to labour utilisation.

a. Trip Passenger Index (TPI);

This measure relates passengers as an input of the system and the number of trips carried out, either by an operator or by a specific route. Higher index leads to higher performance for the operator and at the same time less comfort to the passengers.

b. Kilometre Passenger Index (KPI);

Similarly to the previous index, this one relates passengers carried and the total distance travelled either by one operator or by one route. Both indexes include dead distance.

This index is one of the most crucial in setting operators revenues as their operating costs are proportioned to the distance travelled. Consequently, the higher this index the higher the remuneration per distance travelled.

c. Kilometre per Vehicle(KM-VE) and Kilometre per Operational Fleet (KM-OP);

This measurement relates the distance travelled per vehicle or fleet utilisation. The higher the rate the higher the vehicle utilisation.

d. Employees per Vehicle (TE-VE);

This measure relates to the labour utilisation and its relation to the fleet. For employees is being considered those involved directly with the provision of the services such as drivers, conductors, supervisors and maintenance workers.

IV.2.2.3- Revenue Measures.

Before defining revenue related measures, it is important to stress that revenues here applies only to fare box revenues.

a. Revenue per Kilometre (REV-KM);

This index is defined as the remuneration per distance covered by the route or the operator. It is the most important of the revenue measures in the sense that costs are also proportioned to the distance travelled.

By maximising this measure, operators will be maximising their profits.

b. Revenue per Passenger (REV-PASS);

This rate refers to the ratio between collected revenues and passengers transported.

c. Revenue per Vehicle (REV-VE) and Revenue per Operational Fleet (REV-OF);

This efficiency indicator relates to the revenues per vehicle or per fleet.

d. Revenue per Trip (REV-TRIP);

Here revenue is related to the ratio between collected fare revenues and the number of trips carried out.

IV.2.2.4- Capacity Measures;

a. Load factor (LF);

This index relates utilised capacity (demand) and offered capacity (supply). The supply is the sum of the seated and standing capacities. The supply per trip is assumed to be 130 passengers, or approximately two times the official maximum capacity including standing passengers and it is related to round trips.

b. Supply per Kilometre (SU-KM);

This index relates potential capacity in numbers of seats offered and the route length.

Operators performance is presented next, and some of the performance measurements defined previously are tested amongst different operators, aiming at establishing any significant difference that might occur within the system.

IV.3- OPERATORS PERFORMANCE.

IV.3.1- Introduction.

In this section the system is evaluated from the supply side, considering operating records from the private enterprises.

According to Fielding (op. cit.), statistics on transit efficiency are more reliable than those on effectiveness. Service utilisation is difficult to measure accurately and operators have far less control over the utilisation of services than they have over its supply.

Operators overall performance may be influenced by many aspects, such as ownership of the services, operators size, and the area where services are being provided.

In the case of Rio de Janeiro, a comparison between private and public operator does not seem feasible; not only because of the lack of compatible data but also because of the uneven share between private and public operators, approximately 96% for the former and 4% for the latter (Chapter III, Table IX).

The analysis will be carried out on a comparative basis and two approaches are considered; an economic and a spatial one. The first one focuses on the operators size and the utilisation of their services and the second focuses on the area where services are being provided. According to Fielding (op. cit.), classifying transit into groups helps analysts to understand variations between them and the strategic opportunities available for each type of agency.

The purpose of this analysis is to determine to which extent operators performance is a result of their size or if there is also a spatial determinant accounting for their performance as well, or even both possibilities together.

It is important to stress that performance will be mainly derived from fare box revenues, as no data related to running or fixed costs were available.

IV.3.2- Operators Economic Analysis.

The economic analysis considers operators according to their size and to the utilisation of their services. Size comprises of both fleet in operation and number of routes operated. Some performance measurements are selected for the utilisation of services analysis such as, kilometre per vehicle, passenger per vehicle and kilometre passenger index.

There is little evidence of large economies of scale in the bus industry according to the size of the companies (Savage, I., 1985). A study of the British bus industry by Lee and Steedman (1970) found very few economies of scale, the only exception being related to maintenance costs, where a "U" shaped relationship relative to the operator size was observed.

Fielding and his colleagues have developed a typology for bus transit performance and found that there were considerable differences among the 311 motor bus systems in the U.S. (Fielding, op. cit.). In their study, cluster analysis techniques were used to differentiate bus transit systems into twelve groups, each of them distinctive in nature and composed of agencies with similar operating characteristics.

The characteristics used to create the typology were size (the number of vehicles required for peak service), peak to base operating ratio and average operating speeds. While the first two characteristics were useful predictors of the cost of producing service, the last one distinguished between suburban and small city systems (fast) and central city systems (slow).

The results of Fielding's work indicated that diseconomies of scale did exist in transit: smaller and midsized agencies were more cost efficient than larger ones.

The economic analysis of the Rio de Janeiro bus industry will consider operators according to their fleet size which is the first variable to be tested. One of the 33 private operators and the public operator were not considered at this analysis, owing to the lack of data.

Operators are classified according to their fleet size; eighteen small (120 to 141 vehicles), seven medium (156 to 210 vehicles) and seven large enterprises (223 to 346 vehicles on average). The criteria for grouping the operators considered similar fleet sizes, rather than grouping them into three sub samples of same size.

It is expected that larger operators generate more trips, carry more passengers, cover longer distances and consequently generate higher gross revenues, which is confirmed from the results shown in Table I.

TABLE I

1988 ANNUAL OPERATORS RECORDS ACCORDING TO THEIR SIZE (January to October)

Size	Bus Trips	Passenger Trips	Travelled Kilometre*	Fare Box Revenues(NCZ$)
Small	237,552	23,120,000	10,130,000	850,000,000
Medium	374,424	33,540,000	14,180,000	1,150,000,000
Large	503,846	53,170,000	21,460,000	2,010,000,000

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro, compiled by the author.

* including dead mileage.

In order to establish differences that might occur among these three types of operator, some performance measurements defined in section IV.2.2, are calculated utilising the records presented in Table I.

Table II presents some performance measures and some operating characteristics according to the operators' fleet size.

TABLE II

OPERATORS PERFORMANCE ACCORDING TO FLEET SIZE

Performance	Average Fleet Size (vehicles)		
Measures	Small (128)	Medium (176)	Large (282)
Number of Routes	8.6	14.1	18.7
Trip Length (Km)	48	40	43
Kilometre Pass Index	2.30	2.37	2.52
Trip Pass Index	97.80	94.11	106.12
Rev-Km	83.64	81.53	94.36
Rev-Veh	6,600,000	6,500,000	7,100,000
Rev-Trip	3,793	3,249	4,056
Km-Veh	79,068	80,630	76,752
Pass-Veh	181,577	190,507	189,330

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro (January to October), compiled by the author.

From the data presented in Table II, the only index that has presented a clear discernible pattern according to fleet size was kilometre passenger index, the larger operators being the most efficient ones. All other measures did not present any discernible pattern according to the size of the fleet in operation.

Overall, large operators achieved higher performance figures as they presented the lowest utilisation of their vehicles, considering distance travelled. Simultaneously, they have achieved the second highest figure for passenger per vehicle (close to the first figure) and the highest kilometre passenger index, consequently they have maximised their figures for revenue per kilometre, per vehicle and per trip.

Medium size operators have presented the lowest performance in the three operator categories, if all the revenues measures are considered. However, they presented the highest utilisation of their vehicles in terms of distance travelled and passengers transported. These results may be explained by the ratio between utilisation of their vehicles considering distance travelled and passengers per trip. If it is considered that medium size operators run the shortest trips, it would be expected for them to present the highest figure for KPI, but this did not occur because they have presented the lowest figure for trip passenger index.

From this initial analysis it cannot be concluded that better performance is totally explained by operators size. Although larger operators presented higher performance, smaller ones did not necessarily present lower ones. Certainly some economies of scale may occur as the larger operators presented the highest performance. However, the lack of information concerning their operating costs may constrain further conclusions regarding profitability. Maybe other characteristics may influence their performance more significantly.

Next the number of routes are considered as a possible explicative factor, influencing operators performance. Table III presents operators' performance according to the number of routes they run. Fourteen operators running from five to eight routes were classified as small ones, ten operators with nine to sixteen routes were categorised as medium ones and finally eight operators with eighteen to twenty nine routes were considered large ones. Again, the grouping criteria was to categorise operators according to similar number of routes, regardless of how large each sub group was.

It is important to stress that fleet size and number of routes are positively correlated. If operators are analysed considering number of routes, a slightly different picture is drawn in comparison to their fleet size. But the differences that are observed here will enable an understanding of what are the key explanatory variables that influence operators overall performance.

Revenues per kilometre seems to be the main variable to measure operators performance. This figure, analysed from Table III, shows that medium size operators were the ones that presented the highest remuneration per kilometre, but simultaneously presenting the lowest utilisation of their vehicles in terms of distance travelled and the highest figure for passengers per vehicle. As a result of running the shortest trips, they have also maximised their kilometre passenger index. The only index that presented a clear economy of scale was revenue per vehicle, while all the others presented a "U" curve or an inverted "U" shaped curve.

TABLE III

OPERATORS PERFORMANCE ACCORDING TO NUMBER OF ROUTES

Performance	Number of Routes		
Measures	Small (7)	Medium (11.5)	Large (21.5)
Fleet Size	131	184	229
Trip Length (km)	51	38	44
Kilometre Pass Index	2.23	2.60	2.30
Trip Pass Index	101	95	100
Rev-Km	80.75	92.73	84.86
Rev-Ve	6,300,000	6,900,000	7,000,000
Rev-Trip	3,918	3,452	3,755
Km-Veh	78,213	75,830	83,951
Pass-Veh	174,883	195,337	190,688

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro (January to October, 1988), compiled by the author.

On the other extreme one finds small operators achieving the lowest remuneration per kilometre. Assessing their achievements in other variables will permit some conclusions to be drawn regarding their performance.They have carried fewer passengers per vehicle, while their trips were the longest ones. Consequently their kilometre passenger index was the lowest one as well. Their highest figures for revenues per trip is explained as a result of operating longer journeys, making fewer trips, and consequently revenues per trip achieved higher values.

As a partial conclusion it may be said that operators should minimise the journey distance but simultaneously maximise the use of the capacity they offer. If these two goals are achieved, operators will be maximising their kilometre passengers index and consequently their revenues per distance travelled. Their operating costs are proportioned to the distance travelled. Consequently, their profitability will increase as their revenue per kilometre is maximised. In practice it appears that operators who operate shorter routes within areas of higher density are the ones that achieve the highest utilisation of their services and consequently higher remuneration and profitability.

So it seems that better performance from the economic perspective does not necessarily derive from operators' size, but the utilisation of services or the maximisation of the services provided.

Differing from studies in America and British, the Rio de Janeiro bus industry seemed to indicate that some economies of scale do exist within its industry.

The next step is to analyse how operators perform, according to the three utilisation measures that seemed to be crucial in setting up operators performance. These are vehicle utilisation, where both passenger and distance per vehicle are considered, and also the ratio between passenger and distance travelled (KPI).

Operators were categorised according to the annual distance travelled into low utilisation operators (62,000 to 72,000 Km-Veh), medium utilisation (73,000 to 82,000 Km-Veh) and high utilisation (83,000 to 102,000 Km-Veh). Sample sizes were respectively 6, 19 and 7 operators. In Table IV their performance is presented according to the distance travelled.

TABLE IV

OPERATORS PERFORMANCE ACCORDING TO ANNUAL DISTANCE TRAVELLED- (January to October ,1988)

Performance	Average Annual Distance Travelled (Km)		
Measures	Low (68,786)	Medium (78,412)	High (88,909)
Fleet Size	223	160	161
Number of Routes	12.3	11.4	13.5
Trip Length (Km)	43.4	45.8	44.8
Kilometre Pass Index	2.64	2.30	2.30
Trip Pass Index	110	93	102
Rev-Km	96.01	83.35	82.42
Rev-Veh	6,500,000	6,500,000	7,200,000
Rev-Trip	4,494	3,626	3,706

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro, compiled by the author.

From the results shown in Table IV it can be concluded that the operators who achieved the highest remuneration per kilometre are the ones that have presented the lowest utilisation of their vehicles in terms of distance travelled, and the highest kilometre passenger index. Average trip length did not differ significantly among the three operator categories, nor did the number of operated routes. Also it is clear that the lower the utilisation, the larger the fleet.

If medium and high utilisation operators are considered, some interesting results are observed. No significant differences were detected between their fleet sizes, number of routes, kilometre passenger index and trip length, and revenues per kilometre and per trip. These figures lead to the conclusion that the maximisation of passengers per kilometre is the key index that results in a higher remuneration per distance travelled. It is important to remember that running costs are proportional to the distance travelled, so by maximising net revenues per distance travelled, profitability is also being maximised.

If revenue per vehicle is analysed, one observes that operators with low and medium utilisation presented similar figures, although their fleet size differed. This leads to the conclusion that lower utilisation operators have also presented a higher net revenue than medium operators.

Table V presents operators performance according to the utilisation of their vehicles in terms of passengers transported from January to October, 1988. Nine low utilisation operators carried on average 140 thousand passengers, thirteen medium utilisation operators carried 182 thousand passengers and ten high utilisation operators achieved figures such as 229 thousand passengers per vehicle.

TABLE V

OPERATORS PERFORMANCE ACCORDING TO TOTAL PASSENGERS TRANSPORTED PER VEHICLE IN 1988 (January to October)

Performance	Passengers Transported per Vehicle		
Measures	Low	Medium	High
Fleet Size	166	176	172
Number of Routes	9.5	13.4	12.5
Trip Length (Km)	58	41	39
Kilometre Pass Index	1.82	2.35	2.86
Trip Pass Index	92	95	110
Rev-Km	74,88	84,86	95,95
Rev-Veh	5,700,000	6,600,000	7,600,000
Rev-Trip	4,140	3,468	3,707
Km-Veh	76,813	78,681	81,074

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro, compiled by the author.

Demand seems to be the system input that influence operators overall performance more directly. Five out of six indexes, KPI, TPI, REV-KM, REV-VEH and KM-VEH, presented clear economies of scale within the Rio de Janeiro bus industry, the only exception being the index REV-TRIP, that presented a "U" shape relationship.

Also from Table V it became more evident that operators utilisation is not necessarily influenced by their size, considering both their fleet and number of routes, but it is directly proportional to trip passenger index, and inversely proportional to trip length. Here it seems possible to conclude that the shorter the journeys' length, the higher the turnover.This in turn seems to explain the operators highest remuneration per kilometre.

Kilometre Passenger Index- KPI is one of the key indices used by local authorities in most Brazilian cities to set up fare levels. As stated in Chapter III (III.5.3), demand is taken into account as operating costs are shared equally by all route users. Consequently trip length and demand are important variables in setting fare levels.

Table VI presents operators performance according to kilometre passenger index- KPI. The sample distribution by KPI was the following: 5, 16 and 11 operators with low, medium and high utilisation, and 1.54, 2.23 and 2.92 passengers per kilometre respectively. Again the grouping criteria considered operators with similar figures for KPI, and did not grouped them according to similar sample sizes.

TABLE VI

OPERATORS PERFORMANCE ACCORDING TO KILOMETRE PASSENGER INDEX- KPI.

Performance	Kilometre Passenger Index (KPI)		
Measures	Low (1.54)	Medium (2.23)	High (2.92)
Trip Length (Km)	69.5	42.7	37.6
Number of Routes	12.4	12.0	11.9
Fleet Size	158	165	189
Trip Pass Index	88	95	109
Rev-Veh	5,800,000	6,400,000	7,400,000
Rev-Km	73,34	80,35	98,60
Rev-Trip	4,379	3,450	3,684
Km-Veh	79,717	80,416	76,332
Pass-Veh	123,284	179,305	221,994

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual Operating Report, Rio de Janeiro, compiled by the author.

It is clear that the shorter the trip length, the higher the KPI. The number of routes did not seem to alter this utilisation index, but fleet size presented a slightly positive correlation. The Kilometre Passenger Index explains both revenues per kilometre and also per vehicle, as highest figures for KPI led to highest revenues index both per distance travelled and per vehicle in operation. From KPI the existence of economies of scale within Rio de Janeiro bus industry is evident, the only exception being the index REV-TRIP.

However, KPI may be misleading, as not all costs are proportional to the distance travelled. According to White (1976), operating cost in the bus industry can be related to three main variables: *time*- interest payments on capital, depreciation, management and wage are related to the passage of time rather than distance operated or even seats provided; *mileage* - fuel, tyres and some maintenance costs are related to mileage directly; *peak demand*- changes in peak service provision create needs for changes in the number of vehicles and crews; these in turn affect depreciation, depot costs, wages and salaries; additional staff employed for the peak periods may often be paid a guaranteed day, irrespective of the amount of time actually spent on duty.

The traditional practice of bus operators in allocating all costs to a single total which is then divided by the distance covered may obscure these major differences pointed out above (Moyes and Willis, 1974).

Table VII presents a summary of operators performance according to their revenue per kilometre. Operators were put into eleven high performance categories that achieved revenues from 91.52 to 116.25 Cruzados per kilometre; eleven medium performance, with a range in their revenues from 80.86 to 88.84 Cruzados per kilometre and finally ten low performance ones that presented revenues from 49.16 to 78.36 Cruzados per kilometre. The criteria for the grouping considered operators with similar ratios. By coincidence the three groups presented an even sample distribution.

From Table VII it becomes more evident that operators performance is more strongly related to their fleet size and to a less extent to the number of routes they run . Their performance is also a function of the utilisation of their services and both index passenger per kilometre and per trip seems to explain their achievements quite well. As stated before, operators performance is inversely proportional to the distance travelled , and this supports the argument that better performance is a combination of optimal objectives such as maximum utility of services per kilometre run and minimum distance travelled per vehicle.

TABLE VII

OPERATORS PERFORMANCE ACCORDING TO REVENUES PER KILOMETRE

Performance	Revenues per Kilometre		
Measures	High (99.42)	Medium (84.83)	Low (71.00)
Fleet Size	200	175	139
Number of Routes	13.3	13.0	9.6
KPI	2.86	2.20	2.00
TPI	107	102	86
KM-VE	75,738	79,528	81,698
PASS-VE	215,277	174,486	163,985
REV-VE	7,511,000	6,741,000	5,809,000
Supply*	52,320,000	39,780,000	34,670,000
Demand**	41,810,000	30,500,000	22,770,000
Trips Made	399,967	305,115	266,792
Total Distance	14,890,000	14,000,000	11,390,000
Gross Revenues	1,480,000,000	1,185,000,000	807,000,000

SOURCE: Rio de Janeiro Private Operators Trade Union 1988 Annual

Operating Report, Rio de Janeiro, compiled by the author.

* Supply- seats offered ** Demand- passengers transported.

The next step investigates which operators have presented higher performances and to identify where they run their services to test whether or not the spatial variable also influences their performance.

Among the eleven operators that achieved the highest revenues per kilometre rates, three of them, Verdun, São Silvestre and Real are operators running their services typically within wealthier areas. From the total routes operated within wealthier areas, 46% have achieved the highest revenues index, while only 20% of those operating within poorer areas did so. This gives some evidence to support the argument that performance is also related to a spatial component, or in other words higher density areas promote a higher utilisation of services and turnover, what in turn leads to higher fare revenues.

The next section will follow the analysis of the system from a spatial perspective, where performance will be analysed according to operators route types, or in other words where their services are being provided.

IV.3.3- Operators Spatial Analysis.

In this section a spatial analysis is carried out considering the routes by type, which means each route type operates within or between different zones. So here the objective is interested to establish whether or not performance rates are influenced by the area where services are being provided.

From almost 380 routes of the 32 private operators and the public operator combined, 220 routes were select for the analysis, because the routes with any missing data were deleted at this stage. From this figure, 22 routes are operated by the public operator CTC-RJ.

As stated in Chapter III, the system network is divided into five route types, each of them attending areas with different patterns of income distribution. So, North Radial (NR) routes link peripheral areas to the Core, being considered a route type serving basically poorer areas to the CBD; North Local (NL) routes run mainly within the very extensive Northern area, covering parts from the Core as well as from both Peripheries; Diametrical (DI) routes link Northern to Southern zones via the Core.They represent a composition of North and South Radial routes, consequently they serve both poor and wealthy areas; South Local (SL) routes operate exclusively within Southern zone boundaries within the Core, being routes typically serving wealthy areas. Finally South Radial (SR) routes link Southern zone to the Core, also covering exclusively wealthy areas. A summary relating route types and areas they serve is presented below.

Route Type	Type of Link
North Local	Poorer-Poorer (P-P)
North Radial	Poorer-CBD (P-CBD)
Diametrical	Poorer-CBD-Wealthier (P-CBD-W)
South Local	Wealthier-Wealthier (W-W)
South Radial	Wealthier-CBD (W-CBD)

Table VIII shows the distribution of the selected routes, regardless of operator but by type, and the respective percentages as well as the percentage for the total routes operated, providing evidence that the sampled routes are representative.

TABLE VIII

SAMPLED ROUTES DISTRIBUTION BY TYPE

Type	Number of Routes	%	% total routes
North Local (NL)	107	48.5	57
North Radial (NR)	50	23.0	23
Diametrical (DI)	22	10.0	6
South Local (SL)	21	9.5	7
South Radial (SR)	20	9.0	6
Total	220	100	100

Performance measures similar to the ones used in the economic analysis are also used here to check whether or not performance is influenced by any spatial characteristic referring to income, wealth distribution and land use. It is argued that land use plus income and wealth distribution play a decisive role in setting up travel patterns and also in determining demand for transport. So there is evidence that operators performance is also influenced by some spatial characteristics.

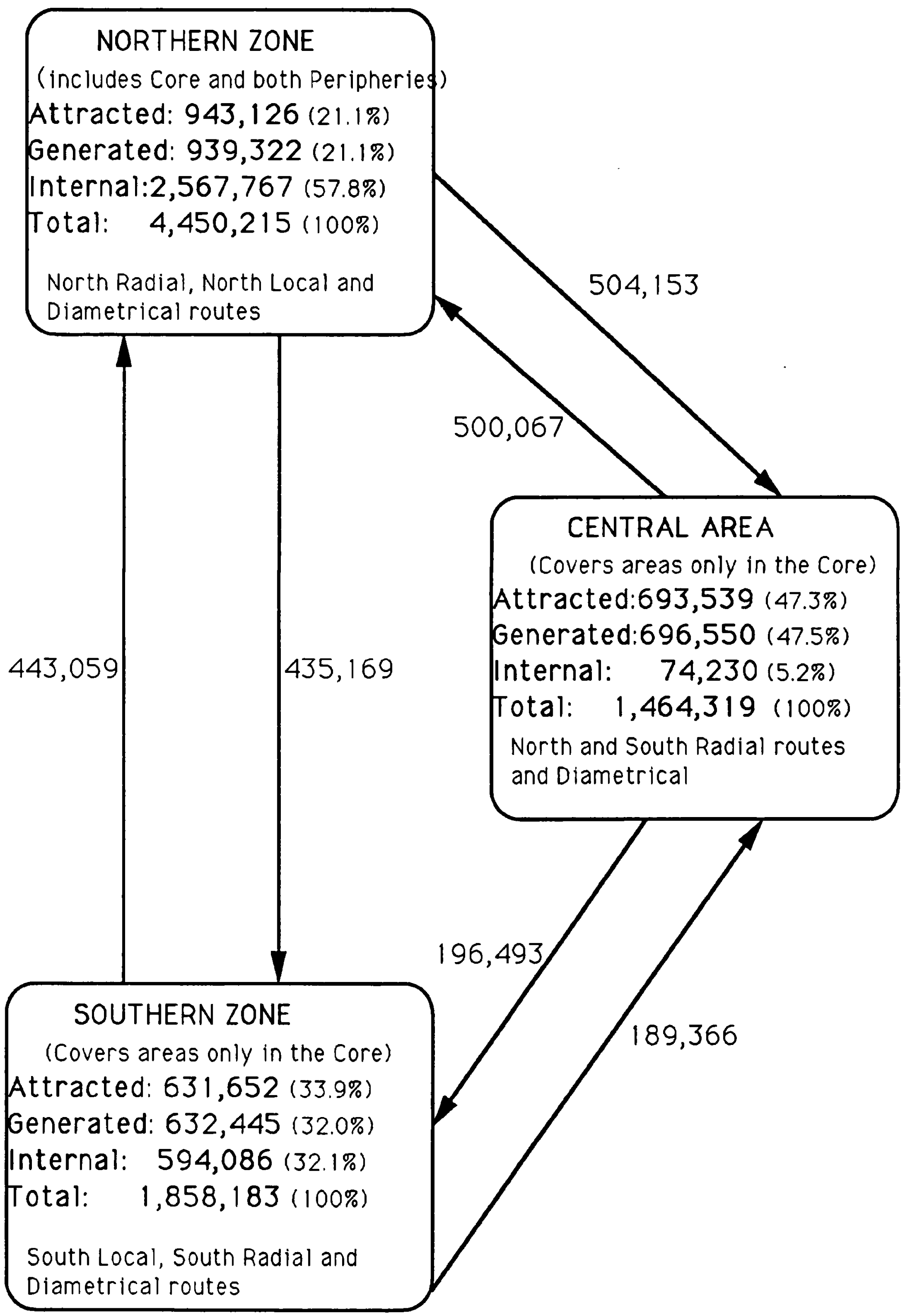
Diagram I presents the distribution of the demand among three main areas: Northern Zone which includes areas in the Core and both

DIAGRAM I

DAILY TRIP DISTRIBITION BY PUBLIC TRANSPORT IN RIO DE JANEIRO

Source: Plano Urbanístico Básico do Rio de Janeiro, PUB RIO, 1977

(compiled by the author)



Peripheries; Central Area, mainly related to the CBD areas in the Core and Southern Zone, exclusively within the Core boundaries. This diagram shows that 72% of the trips attracted to the Central area have the Northern Zone as their origin, while 53% of the trips generated within the Northern Zone have the Central area as their destination, while for the remaining 47% destination is the Southern Zone. These trips may be the ones that require interchange, especially if they originate in peripheral areas. It is also worth noting that within the Northern Zone the internal trips accounted for almost 60% of the total trips within that area. Within the Southern Zone a more even share is observed among attracted, generated and internal trips (around 32% each) while in the Core the internal trips accounted for only 5% of the total trips in that area, providing evidence that this area attracts more trips from residential areas than any other due to the concentration of the labour market within its boundaries.

Table IX presents some average results from the operators side, according to their route types. The performance measurements selected for the analysis are trip length, kilometre passenger index, trip passenger index, kilometre per vehicle, passenger per vehicle, revenues per kilometre. Two measures considering supply were also included; These are the available capacity by the effective distance travelled (SUPPLY-KM) and the ratio between effective demand and available capacity (PASS-SUPPLY). Figures related to fleet size are also presented.

The results presented in Table IX need a very careful interpretation. It is clear that the utilisation of the vehicles in terms of kilometres is proportional to trip length. North Radial routes presenting longer journeys have consequently achieved higher vehicle utilisation, while on the contrary the South Local and South Radial operate shorter routes and presented a lower vehicle utilisation.

TABLE IX

OPERATIONAL PERFORMANCE BY ROUTE TYPE

Performance Measures	Route Types NL (P-P)	NR (P-CBD)	DI (P-CBD-W)	SL (W-W)	SR (W-CBD)
MEAN FLEET SIZE	15.73	20.82	25.41	12.19	19.00
TRIP LENGTH (Km)	38	64	45	32	25
KPI	2.94	1.87	2.53	2.65	2.42
TPI	100	96	111	64	77
KM-VEH	76,900	90,120	80,800	63,150	70,400
PASS-VEH	217,335	150,641	203,832	165,192	170,284
REV-KM	.097	.081	.094	.090	.092
SUPPLY-KM	4.28	2.60	3.35	5.08	4.55
PASS-SUPPLY	.767	.728	.842	.522	.605

If the supply offered per kilometre or the potential supply is analysed it can be concluded that North Radial routes have offered less seats per kilometre; 2.60, while on the other extreme South type routes offer almost double, (5.08 and 4.55). Is this imbalance on the supply side a response to cope with the higher effective demand within the wealthier areas? When the ratio between passengers transported (demand) and seats offered (supply) is observed, the conclusion is that services operated within wealthier areas (Southern type routes) are far over supplied in comparison to services provided within poorer areas (Northern type routes).

The utilisation of services considering passenger kilometre index is also inversely proportional to trip length. It was argued in the previous section that revenues are a function of maximising the ratio between passengers carried out per kilometre. From the results presented in Table IX it is evident and expected that North Radial routes have achieved the highest utilisation of their vehicles (Km-Veh), the lowest KPI and remuneration per kilometre while North Local routes the highest figures for both of these performance measures, which in turn may be explained by the high rates of local trips generated within Northern Zone, as shown in Diagram I. The other three route types shared intermediate figures, but very similar to one another. So the argument that revenue is a result of maximisation of passengers per kilometre is also supported here.

When demand is analysed per trips carried out, North type routes presented the highest figures as well as Diametrical ones, and Southern type routes the lowest figures. Could these results be interpreted as an imbalance in supply matching demand in poorer areas? Certainly the Northern routes and Diametrical users may not have alternatives, either by private transport or other public modes, while Southern routes operate within areas of higher car ownership levels, where more alternative route types are available and in some parts there is also the alternative of the underground.

There was no evidence from the data referring to the fleet allocation to support the argument that wealthier areas are necessarily provided with more vehicles on their routes, but must be taken into account that North Local and Radial routes cover an area much more extensive than Southern routes and also corresponds to areas of higher population rates.

On the one hand it is clear from these results that routes that operate within poorer areas or between poorer areas and the Core (mainly North Radial, and Local) are the most overcrowded ones (higher figures for Pass-Veh), but at the same time they are the least profitable ones. On the other hand the ones that operate within wealthier areas or between wealthier areas and the CBD (South Radial and Local, Diametrical mostly) offer a less crowded service and generate more revenue. In the next section it will also be possible to test reliability of services among different areas in Rio de Janeiro. The explanation for these results concerning loading and profitability may be the low turnover in the peripheral-core link, in contrast to high turnover within route types operated exclusively within the core.

So for an operator it seems much more attractive to operate Southern type routes, or within wealthier areas or between these areas and the Core, where more passengers are transported, and travel on average shorter distances which leads to higher turnovers. These routes are the ones that minimise distance travelled and simultaneously maximise their utilisation, in terms of passengers per kilometre.

Performances may be also influenced by some other operating characteristics of the different route types. These may influence patronage; fare levels, trip lengths, running times and operating speed, that in turn may influence operators running costs, and consequently their revenues. These variables are tested among the five different route types, aiming at establishing any significant differences that are likely to occur. Table X presents the average trip length per route type.

TABLE X

AVERAGE TRIP LENGTH (KM)

Route Type	Average (KM)	Sub-total (Km)
NL	25	2,662
NR	33	1,635
DI	22	492
SL	23	484
SR	21	431

The results presented in Table X are important given that operating costs are proportional to route distance, consequently North Radial type routes are the most costly routes to operate. Obviously, profitability will also depend on the patronage of each route type.

The length of routes plays an important role is setting up fares. As mentioned before, the fare is calculated in accordance to the length of the journey. So, North Radial routes will be charged higher fares than the other route types. A high positive correlation of .676 was observed between fares and journeys' distance. In the appendix, the correlation between distance and fare levels is shown.

The distribution of the route types according to the ten different fare categories in Rio de Janeiro is presented in Table XI.

TABLE XI

FARE CATEGORIES BY ROUTE TYPE

Route Types	Fare categories									
	I	II	III	IV	V	VI	VII	VIII	IX	X	
NL	31	30	142	8	7	-	2	3	-	-	
NR	-	1	38	12	2	9	8	7	4	5	
DI	-	3	28	-	1	-	-	-	-	-	
SL	-	-	19	1	3	-	-	-	-	-	
SR	-	1	22	-	-	-	-	-	-	-	
Total	31	34	249	21	13	9	10	10	4	5	386

From Table XI one notices that the most representative fare level is category III, charged on 249 from the 388 routes. Higher fare categories are mostly charged on North Radial routes.

Table XII shows the average fare in Centavos, which confirms the figures presented in the previous table. By the time of the secondary data collection (December 1988) the category fare III was 14.0 Centavos.

TABLE XII

AVERAGE FARES BY ROUTE TYPE

Route Type	Average
NL	13.7
NR	21.6
DI	14.1
SL	13.9
SR	14.0

If the figures for North Radial routes, which provides services mainly between Peripheral areas and the Core are taken, it is evident that their fares are on average approximately 50% higher than the fares charged on the other four route types.

It is interesting to link these results with the socioeconomic pattern of the population and their most representative pattern of trips. Most of the poorer segments of the population live in peripheral areas but they are still forced to work in the Core. So the most typical route type for this journey pattern is North Radial routes. Given that this population is less well off and that this route type is charged higher fares, the relative costs of transport for those under such conditions will certainly be relatively higher in a comparative basis. Results from the fieldwork will demonstrate this more clearly in the following Chapter. Trip length influences fare levels, and this in turn influences users travel costs.

Journey distance may also influence running time, which is presented in Table XIII.

TABLE XIII

MORNING PEAK AVERAGE RUNNING TIME (MIN.)

Route Type	Average
NL	67.62
NR	65.52
DI	58.92
SL	77.70
SR	58.38

Running time is not necessarily related to journey distance, otherwise South Local route types would not have presented the highest figures. Running time is explained more by traffic than anything else, and within the Core area, where the highest car ownership level is observed. This could lead to lower operating speeds for the routes operating there. It is not by chance that most of the measures attempting to alleviate traffic conditions are being implemented within the Southern Zone, in the Core. For example, bus lanes have been implemented and main corridors converted to one way according to the major traffic direction in different peak periods. Apart from traffic flows, running time is also under the influence of bus stop frequency, traffic lights along the route, parking and finally dwell time. So, Southern route types may present higher dwell time due to higher turnover.

To confirm the hypothesis that travel time is under influence of traffic, Table XIV presents average operational speeds for the morning peak period.

TABLE XIV

MORNING PEAK AVERAGE OPERATIONAL SPEED (KM-H)

Route Type	Average Speed (Km-H)
NL	22.4
NR	29.7
DI	23.3
SL	17.7
SR	21.3

Results for operational speed seems to be consistent with running time, and again South Local routes have presented the lowest average values, while the highest average values belong to North Radial routes. The other three route types have presented similar average values around 21 Km-H. Operating speeds are particularly important in assessing a mass transit system as it affects running time, frequency and reliability of the services and consequently operating costs. In a mixed traffic road, along main corridors where heavy traffic is almost constant throughout the day, buses usually achieve average speeds of 12 Km per hour, falling as low as 9 Km per hour nearer to city centres. Where bus lanes do operate, speeds can increase up to 15 to 20 Km per hour. In Chapter VII some figures related to the implementation of bus lanes in Rio de Janeiro are presented.

No data concerning running costs was available, but it seems that North Radial routes are penalised by operating longer routes while Southern route types are penalised by operating at very low speeds which is likely to increase their fuel consumption. These two extreme route types may somehow achieve a balance concerning their operating costs.

IV.4 - CONCLUSION.

The analysis of the system from the supply side allows one to conclude that operators perform differently. Their performance is a function of maximising the ratio between potential supply and effective demand. Demand on the other hand is a function of land use and how activities are distributed within the urban fabric.

Therefore operators' performance is in fact a function of a combination of factors which involves their size, both number of vehicles and number of operating routes and the areas where services are being provided. If from their perspective they achieve a better performance by maximising the utilisation of their services in order to to maximise profits, what would be the quality of the current service provided to users? What would be the impacts on the users side given a more profitable operator or route type?

One may argue that by maximising their services utilisation, operators will be neglecting the quality of their services by over crowding vehicles, increasing headway and so forth.

Differently from the studies carried out in America and Britain, results have shown in this study that when operators are analysed by their size, the larger operators, on average, have performed better than smaller ones, what may lead to some economies of scale within the Rio de Janeiro local bus industry.

On the spatial analysis it was possible to conclude that shorter route types achieved higher performance than longer ones. Shorter routes happen to operate within wealthier areas where a higher turnover was observed. It can be concluded that these routes operated within wealthier areas are the ones that generally have achieved higher performances.

When some operating characteristics are analysed that as a result of their running costs may influence operators performance, such as operating speed and running time, it can be concluded that on one extreme may be found longer route types more costly to operate, balanced by shorter route types which have presented slower operating speeds, which in turn may increase their operating costs.

In conclusion it can be said that operators or routes run within wealthier areas are the most likely ones to generate higher revenues as a result of the balance between demand and supply within and between these areas (no significant variations were observed during the day, given different directions of the journey) and also operating characteristics of the routes that provide these services.

The analysis from the users perspective which is developed in the next Chapter, will clarify and support the argument that wealthier areas are offered a better service.

CHAPTER V - SOCIAL ANALYSIS

V.1- INTRODUCTION

This Chapter analyses the bus system from the demand perspective. It became evident in Chapter IV that operators perform differently and the reasons were mainly related to their size in terms of their fleet dimension and number of routes operated, the utilisation of their services and finally a spatial dimension, namely where their services were being provided.

If they perform differently, would the level of their services vary according to these factors that had influenced their overall performance? Could these differences in the level of service be related to the socioeconomic distribution of the population or to the city structure, or even both simultaneously?

The aim of this Chapter is to investigate inequalities in services, considering different areas of provision from the socioeconomic view and from the users perspective. The main hypothesis is that services are unevenly distributed, and that wealthier areas are offered a better service to the detriment of poorer areas. In order to test this hypothesis and to support it, an extensive survey of the Rio de Janeiro bus system was then carried out in 1989.

Among other classical attributes of effectiveness, a better service is considered to be related to the availability of services, the frequency of services, reliability, comfort, safety. The quality of services can be evaluated mainly through these effectiveness measures. These attributes can be defined in many different ways, especially if they are being considered from different perspectives.

Much research on attitudes toward transportation studies were conducted during the late 1960s and early 1970s. Some were intended to expand demand modelling by providing a behavioural element, while others examined attitudes toward transportation improvements (Fielding G. op. cit.) .

Some conclusions drawn from Wachs' review (1976) on these studies to determine consumer attitudes toward transit service were: while most operating improvements attempt to reduce in-vehicle travel time, travel time reliability may be a more important factor than total elapsed travel time in determining consumer response to transit improvements; partial times like walking, waiting and transferring are more onerous than time actually spent in-vehicle; fare reductions are probably less important than travel time.

Some of these findings may be not totally applicable to the Brazilian situation. In the specific case of Rio de Janeiro, where travel time (in-vehicle) and travel costs are very important issues and that affect most of the actual users and potential ones, especially those living in peripheral areas. Any attempt to reduce both is important, considering that most of the transit captive users are low income earners and commuting time for this group may reach figures approaching four hours every day, and may represent in financial terms up to one third of an individual's earnings. So, even from the users perspective, these attributes may be evaluated differently taking into account different socioeconomic groups. Maybe for higher income groups travel time is more important than cost savings, while for lower income groups any increase in travel costs may represent cuts in other essential commodities or even make travel impossible.

The next section presents some attributes through which the system will be assessed, considering the data collected in the field mainly from the users perspective.

V.2- ATTRIBUTES.

V.2.1- Introduction.

The attributes that will enable the evaluation of the system from the users perspective are presented and defined in this section. It considers the primary data collected in the field to support the argument that differences in the quality of services occur and that they are clearly related to the socioeconomic segregation of the population and also to the land use pattern.

Basically the following attributes are considered in this analysis: accessibility, reliability, comfort and convenience, and safety. Most of these attributes will be assessed mainly by the analysis of travel time and travel costs. Travel time comprises of all the component times such as walking, waiting and travelling in-vehicle.Travel costs are mainly concerned with the monetary costs of travelling. Transfers are also analysed as they may increase not only travel time but also travel costs, as transferring implies payment of another fare. Safety is presented in the users evaluation of the system, as they state their previous experience of assault while travelling.

V.2.2- Accessibility.

The notion of accessibility is a very broad concept and it is a very difficult one to define precisely. It may range from physical accessibility, measured by the extent a specific service really provides travel opportunities, to financial accessibility that relates to what extent an available service is in fact affordable to the population that it is designed to serve. For the former view a simple measure such as the percentage of the population living within 400 metres of a bus route gives an indication of travel opportunity or walking time to the stops, while for the latter, fare levels and travel costs are measures that could assess how accessible an available service is.

From the data gathered, accessibility will be measured taking into account mainly walking time, transfers and total travel time and eventually travel costs.

V.2.3- Reliability.

Problems of service reliability are major concern shared by both transit system operators and users. Unreliable services can affect passengers in terms of increased waiting times, higher travel time uncertainty and general dissatisfaction with the system. It leads to additional vehicle requirements and consequently higher operating costs (Abkowitz M. and Tozzi J., 1987).

Reliability is revealed as one of the most important attributes of a bus service in surveys of passengers attitudes toward public transport. Perceptions of reliability may be more strongly influenced by delays on the services . Although being an important indicator of bus services performances, reliability is a very difficult factor to define, to measure and to use the results of such measurement to modify and improve operating schedules.

Usually a highly variable headway is the primary symptom of transit reliability problems. A mathematical model for computing and analysing headway variance of fixed bus routes using basic probability concepts was derived by Adedisi (1984), which results indicated that bus loading conditions and traffic conditions along the route are the major factors contributing to headway variability.

If taken from the operator view point, reliability is much more related to schedule adherence and frequency of their services, while for the user reliability is much more related to waiting times and delays of the services provided.

In the Rio de Janeiro bus system there are no scheduled services, but a minimum fleet that is expected to operate, and the supply will vary according to peak and off peak periods. Given routes mean running times and fleet in operation, a headway may be established and may be compared to real effective headway.

According to the data gathered during the fieldwork waiting time seems to be the most accurate variable to measure reliability of the services, and the one that presented the most significant differences among the three areas under study; Core, Immediate and Intermediate peripheries.

V.2.4- Comfort and Convenience.

Comfort and convenience are also broad concepts that can range from the possibility of travelling seated to overall conditions of the operating system that results in comfort and convenience , such as walking and waiting times, in-vehicle travel time, total travel time, hours of service, number of transfers, stop spacing, crowding ratios and finally some vehicle design characteristics including steps height, floor area, ventilation and interior noise levels.

Data gathered from the fieldwork allows comfort to be evaluated mainly through some vehicle design characteristics, such as steps height, in-vehicle noise levels and loading ratios. Only the last one varied significantly among the core and peripheral areas, while the others did not present any difference at all if considered from the spatial perspective. Vehicles do not differ in design, except in relation to motor location, and t this factor may affect noise levels significantly. However the allocation of the vehicle types are not spatially related.

V.2.5- Safety.

Safety covers concepts from traffic safety to in-vehicle travelling safety taking into account risks of accidents, assault or harassment. There are no statistics available concerning accidents involving buses operated by the private sector in Rio de Janeiro, and the data available for the public operator CTC-RJ does not allow any inferences such as where and when this accidents occurred. Consequently, this attribute will be measured in terms of assault incidents occurring in-vehicle and experienced by the users, as well as their perception in relation to the way drivers behave while driving the vehicles.

V.3- SURVEY METHODOLOGY.

In order to analyse the system from the users' point of view a survey was carried out on Rio de Janeiro bus system. The survey objectives were to support the hypothesis that the bus services were unevenly distributed among different areas considering that population is socially and economically segregated in spatial terms.

To achieve these objectives, a questionnaire was designed to identify some characteristics of the system and the bus users profile as well as their travelling pattern. This questionnaire was divided into two parts: the first one, a technical sheet comprising of vehicle characteristics, trip records, comfort conditions and finally a qualitative evaluation from transport experts' point of view; the second part, an interview addressed to the users aiming at establishing an accurate picture of the system and the quality of services provided. This part was subdivided in two parts; the first one being concerned with passengers socioeconomic status and the second one being related to their travelling habits. While the first part of the questionnaire was completed by a technician at the bus stop, who in this specific case was either the author or a trainee, the second part took place on-board with the passengers being interviewed also by the author and the trainee. A copy of the questionnaire is shown in Appendix I.

During the questionnaire design process, several tests were carried out and partial amendments took place. In Brazil, the preliminary version of the questionnaire was supervised by a Sociologist of São Paulo Traffic Engineering Company (CET-SP), who was responsible for surveys with public transport users. Then a pilot survey was carried out and that version of the questionnaire was tested among bus users on a route that was selected for the survey. At this stage some questions on the interview sheet did not seem to be very easily understood by some passengers and were deleted until a final version was designed, taking into account the pilot survey results.

The on-board interviews were scheduled to take no longer than ten minutes each, and passengers were selected at random. It had to be ascertained, (if they agreed to participate in the survey), that they would not be getting off the bus within the next ten minutes of the journey.

The reason for selecting on-board interviews was the assurance that bus users themselves would be interviewed, the most suitable group to evaluate the system from the demand perspective.Two other alternatives were considered; firstly, interviewing passengers at bus stops, an approach not selected for the survey because users would probably be preoccupied in catching their bus; secondly, interviewing the passengers after alighting, which was rejected as they would be in a hurry to reach their final destination.

The survey was carried out during weekdays at three different periods. At morning peak periods, from 07.00 a.m. to 10.00 a.m., at inter peak from 11.00 a.m. to 15.00 p.m. and finally at afternoon peak from 16.00 p.m. to 19.30 pm. At least two trips were surveyed during each period per route, for three consecutive working days. In total more than 6,500 kilometres were travelled. The survey was carried out from September the 27th to November the 1st, 1989.

The length of the survey and sample size were delimited by time and financial constraints and also because fares and wages were rising on a monthly basis owing to inflation. Fares were increased once, during the first week of the survey.

Passenger acceptance was excellent, and they were very helpful in taking part in the survey, contributing significantly with their experience, criticism and suggestions. Non participation was observed in only three passengers. It was expected that the survey would be successful in this respect. A similar level of acceptance and help was also observed among drivers, conductors and route supervisors.

The survey had the support of the Rio de Janeiro Municipal Transport Secretary. An identification card was issued and the interviewers would board from the front door and did not pay fares. This identification also eased the approach to the passengers as well as to the drivers, conductors and supervisors at the bus stops.

The survey methodology selected fifteen bus routes among the five route types, three for each type, and then the on-board interviews took place. The routes selection criteria considered high demand routes and tried to cover as many different operators as possible.

The population sample size determined thirty interviews per route as the minimum figure so that results could be supported from the statistical point of view. Overall, 554 interviews were made on the following selected routes, grouped into type. On average, 37 interviews were carried out on each route.

South Radial Routes (Wealthier- CBD link);

Route Number	Operator	Origin and Destination	Interviews
125	Verdun	E. de Ferro- General Osório	38
127	Real	Rodoviária- Copacabana	36
175 *	Amigos Unidos	E.de Ferro- Alvorada	33

North Radial Routes (Poorer- CBD link);

Route Number	Operator	Origin and Destination	Interviews
240	Redentor	Praça XV- Cidade de Deus	34
261	CTC-RJ	Praça XV- Marechal Hermes	37
394	Oriental	São Francisco- Vila Kennedy	38

Diametrical (Poorer-CBD- Wealthier link);

Route Number	Operator	Origin and Destination	Interviews
415	Alpha	Usina- Leblon	43
434	Estrela Azul	Grajaú- Leblon	41
484	Auto Diesel	Olaria- Copacabana	34

South Local (Wealthier-Wealthier link);

Route Number	Operator	Origin and Destination	Interviews
512 *	São Silvestre	Urca- Leblon	36
574 *	São Silvestre	São Salvador- Leblon	37
591 *	Amigos Unidos	Hotel Nacional- Leme	35

North Local (Poorer- Poorer link);

Route Number	Operator	Origin and Destination	Interviews
606	Matias	Rodoviária- Eng. Dentro	40
634	Paranapuan	S. Pena- Ilha do Governador	38
638	Três Amigos	S. Pena- Marechal Hermes	34

* Circular routes (origin and destination coincide).

V.4. SURVEY ANALYSIS.

V.4.1. Introduction.

While the secondary data analysis was carried out using the statistical programme Statview 512+ in a micro computer Macintosh SE, the primary data was handled using the SPSS- Statistical Package for Social Sciences, on a main frame computer.

According to the nature of the variables, they were either treated as continuous and remained as such (e.g. travel times and costs), or some of the continuous were categorised (such as age and income), and others were primarily categorical ones (e.g. housing and job location), as were all the qualitative variables.

In a first stage a descriptive analysis was carried out, where the main statistics used were; frequencies, mean, standard deviation, cross tabulation, followed by regression analysis and log linear models.

V.4.2. Log-linear Models.

Log-linear models seemed to be the most suitable statistic analysis method for the data after the descriptive analysis had been carried out. In fact this first stage of analysis suggested which models should be tested.

Log-linear models are a special class of statistical techniques formulated for the analysis of categorical data. These models are useful for uncovering the potentially complex relationships among the variables in a multi variate cross-tabulation. Log-linear models are similar to multiple regression models. In log-linear models all variables that are used for classification are independent variables, and the dependent variable is the number of cases in a cell of the cross-tabulation (SPSS, 1988).

Analysis of data by log-linear models involves several distinct stages. First a plausible model is proposed for the data under study. Next, unknown parameters in the model are estimated from the data, generally by the method of maximum likelihood. Third, these parameters estimates are used in statistical tests of the model's adequacy. Pearson and likelihood-ratio chi-square tests provide overall measures of the compatibility of the model and the data. More specific insight into deviations between model and data are provided by the analysis of adjusted residuals and of selected linear combinations of frequencies (Feinberg, S.E. 1980).

Two possibilities exist at the fourth step. If the model appears adequate, then the parameter estimates are used to obtain quantitative implications concerning the data. At this point asymptotic standard deviations and approximate confidence intervals are major tools. If the model appears inadequate, then the residual analyses and analyses of linear combinations of frequencies at the third stage are employed to suggest new models that are consistent with the data, to which the new model are then applied (Feinberg, S.E. op. cit.).

Thus the analysis will often be an interactive process, in which the four stage analysis is applied to several distinct models, many of which are suggested by previous exploration of the data. There are different ways to assess how well a model fits the data. The test of the hypothesis is one of them and is based on the Pearson chi-square statistic- X_2, as well as on an alternative statistics, that is the likelihood-ratio chi-square. For large sample sizes these two statistics are equivalent (Feinberg, S. E. op. cit.).

Another way is to examine the differences between the observed and the expected cell counts based on the model. If the model fits the observed data well, these differences, called residuals, should be fairly small in value, and not have any discernible pattern. If the model is adequate, the standardised residuals are approximately normally distributed with a mean of zero and standard deviation of one. Standard residuals greater than 1.96 or less than -1.96 suggest important discrepancies at the 95 per cent level of significance, since are unlikely to occur if the model is adequate. Particular combinations of cells with large standardised residuals may suggest which other models might be more appropriate. A model should fit the observed data well, and be substantively interpretable and as simple as possible (Feinberg, S.E. op. cit.).

V.5- SURVEY RESULTS.

V.5.1- Introduction.

Before presenting the results of the survey some data concerning operational records of the routes selected is presented in Table I. These include operating fleet (OF), trip length (TL), average morning peak running time from a survey carried out in 1984 (RT), operating speed (OS), fare level (FL) given in categories (Chapter III), load factor- the ratio between demand and supply (LF), kilometre passenger index (KPI) and finally trip passenger index (TPI).

From the fifteen routes surveyed in Rio de Janeiro, nine operate night services, while the other six stop around midnight, resuming services by four o'clock in the morning.

TABLE I

SURVEYED ROUTE OPERATIONAL RECORDS

Route Number	OF (Vehicles)	TL (Km)	RT* (Min.)	OS (Km-H)	FL (Categories)	LF (D/S)	KPI (Pax-Km)	TPI (Pax-Trip)
125	37	15	35	26	III	.81	3.27	105
127	29	16	50	20	III	.86	3.19	111
175	24	72	153	28	VII	.75	1.73	117
240	18	30	61	30	VI	.61	1.22	80
261	20	28	72	24	III	1.06	3.17	202
394	24	39	55	50	VIII	.78	1.12	102
415	32	27	73	23	III	.82	1.91	107

Route Number	OF (Vehicles)	TL (Km)	RT* (Min.)	OS (Km-H)	FL (Categories)	LF (D/S)	KPI (Pax-Km)	TPI (Pax-Trip)
434	43	26	69	23	III	1.14	2.61	148
484	35	28	61	24	III	.99	2.26	128
512	12	23	84	17	III	.55	2.67	72
574	11	22	83	15	III	.56	3.07	73
591	18	29	110	16	III	.68	3.03	88
606	48	19	57	20	III	.75	2.69	97
634	37	33	79	25	III	1.42	2.89	185
638	54	26	65	23	III	1.07	2.79	139

Source: Rio de Janeiro Private Enterprise Trade Union, 1988 Annual Report, Rio de Janeiro, 1988, compiled by the author.

* CET, Companhia de Engenharia de Tráfego Survey, 1984.

At total 228 trips were carried out among the five route types, from Mondays to Fridays during morning and afternoon peaks and also inter peak periods. This total is divided by the five route types as follows; North Radial, 53 trips; South Radial, 45; Diametrical, 54; North Local, 49 and South Local, 27. This figure for south local routes is due to the fact that all the routes of this type were circular.

In Appendices IV and V some performance indicators are found respectively according to the types of routes and the correlation matrix, while Appendices VI and VII presents respectively the performance indicators for the fifteen routes selected for the survey and the correlation matrix.

The next sections present the results from the survey, first considering passengers economic background and then their travelling patterns. This will allow the establishment of significant inequalities in the provision of services.

V.5.2- Population Socioeconomic Status.

This section presents some socioeconomic characteristics of the sampled population, aiming to support the hypothesis that population is spatially stratified according to their socioeconomic status.

The total sample size was 554 passengers, distributed among the fifteen routes surveyed, from whom 52.2% were male, and 47.8% female users.

The average age of the sampled population was 32 years and their distribution according to six age categories were as following; 10.4% were less than 19 years old, 24.5% between 20 and 25, 37.4% between 26 and 35, 14.7% between 36 and 45, 8.8% between 46 and 60 and finally 4.2% were more than 60 years old.

Some variables are presented such as educational background, occupation, income distribution, tenure, and car ownership. It is believed that educational background plays a decisive role in determining occupation, that in turn will influence income levels.

When the sampled population educational background is analysed, according to a three category grouping (primary school, secondary school and higher degree education), results show that they were respectively 27%, 32% and 39%. Within each educational category there were individuals who had already completed their degree or were still carrying on with their studies.

When population educational background is considered according to their housing location, it is observed that a concentration of more highly educated individuals live within the Core, while in peripheral areas individuals tend to achieve lower education levels. In the Core, it was observed that 21%, 29% and 50% of the sampled population belonged respectively to the three education categories just defined above, while the same figures for Immediate and Intermediate Peripheries were respectively, 26%, 35%, 38% and 47%,39%, 13%.

Analysing the Pearson chi-square, X_2=49.54 with 4 df, conclusion leads to the rejection of the model, at 1% level of significance. Educational background and household location are clearly related. However, the model did not fit the data well and a very uneven distribution of the population among the three areas according to their educational status was observed; while in the Core the figures for observed individuals with higher education was higher than expected and in peripheral areas observed figures for those with lower educational background was also higher than expected.

The observed distribution of population according to educational background reinforces population socioeconomic segregation and certainly plays a decisive role in setting up access to the labour market as well as earnings.

Next, the sampled population occupation is presented. The categories were established according to the Census and at first thirteen groups were considered, which were later aggregated into eleven categories that are presented in Table II, in descending order, according to their frequencies.

TABLE II

SAMPLED POPULATION OCCUPATION

Occupation	Frequency	Percent
Unskilled Workers	101	18.3
Professional Workers	98	17.7
Students	71	12.8
Clerical Workers	62	11.2
Sales Workers	62	11.2
Technical Workers	49	8.8
Unemployed *	39	7.1
Services	34	6.1
Armed Forces	24	4.3
Retired	8	1.4
Others	6	1.1
Total	554	100.0

*includes housewives.

If one takes into account that the survey was carried out during weekdays, from Mondays to Fridays, during peak and off peak periods, a significant percentage of active population would be expected to be either professionals or students. This in fact occurred as 91.5% were active, while only 8.5% were unemployed or retired.

Another factor that must be considered to support the occupation pattern of the population is travel purpose. The main purpose of the journeys were work for 51.3% of the passengers, leisure for 15%, study for 9.9%, shopping for 7%, involved in their work 5.8%, medical for 3.8% and other purposes for 7.2%. The other purposes consisted mainly of searching for a job. It is useful to stress that these figures are consistent with secondary data referred to in Chapter II, where for the whole Metropolitan Region of Rio de Janeiro, travel to work accounted for approximately 48% of the journeys.

The most common occupation observed among the sampled population was unskilled worker, which could certainly be explained by educational background, the lack of better job opportunities, and the existence of an informal market which attracts those with no skills (according to Chapter II, the informal market in Brazil caters for approximately 35% of those engaged in non-agricultural activities).The second most representative occupation was professional worker, which comprised only of individuals with higher degree education, followed by students. Again these rates seem consistent with population educational background. Clerical and sales workers shared the same figures, followed by those technical workers who necessarily hold a secondary school degree followed by those unemployed. Services and

Armed forces workers were the next two categories of active population, and finally are observed those retired, and others.

Occupation was also checked against household location. As the distribution of the sampled population among the three areas of study was not proportional within each of the three spatial areas, it was checked how the spatial population distribution occurred according to occupation. Results revealed that while 25% of the Core householders were professional workers, only 13% and 4% of Immediate and Intermediate Peripheries householders were. On the other extreme if the unskilled workers are considered, only 15% of the Core and Immediate Periphery households were workers with no skills, while within Intermediate Periphery this figure rises to 30% of the population.

Another interesting occupation category to be considered is that of the students. Figures were respectively 16%, 12% and 6% for the Core, Immediate and Intermediate Peripheries households, providing evidence that the Core population has greater access to education. It can also be argued that peripheral householders certainly join the labour market at an earlier age than those of the Core. According to Pastore (1982) 70% of the heads of family in Brazil began to work at the age 14 years or even younger. He also shows that the lower the family income the earlier their members engage in the labour market.

So, 41% of the Core sampled population activities were either professional workers or students, while in both peripheries Immediate and Intermediate, only 25% and 10% were respectively engaged in one of those two occupation categories.

Generally, according to sex, no discriminatory distribution of the population within the considered occupation categories was observed, except for the Armed Forces, where 100% were male and Sales and Services, where 66% and 65% respectively were male. Finally 92.3% of the unemployed were female.

If it is found that housing location and occupation are somehow related, such as the Core households being the ones holding higher positions, it would certainly be expected that incomes are also related to the spatial variable housing location.

Next, sampled population income distribution is presented related to household locations and categorised according to Monthly Minimum Wage- MW (Chapter II), into five groups: up to 1 MW, from 1 to 3 MW, from 3 to 5 MW, from 5 to 10 MW and finally more than 10 MW. (One Minimum Wage is approximately US$50 per month).

From Table III, excluding those with no income, one finds that approximately 36% (202 out of 553) are below three Minimum Wages per month category, from which 57% (115 out of 202) live in Peripheral Areas or Other Areas, that are also peripheral. If higher income categories are observed; 55% (43 out of 73) of those on the 5 to 10 Minimum Wages category live in the Core, while 82% (62 out of 76) of those earning more than 10 Minimum Wages monthly also live in the Core. Moreover, within the Core, 80% (50 out of 62) of those in the highest income category live within the Southern Zone. In this table and in the next two ones, the Core is subdivided into three sub-areas. These are; Central Area, Northern Zone and Southern Zone.

TABLE III

SAMPLED POPULATION INCOME DISTRIBUTION BY HOUSEHOLD LOCATION

Household Location	Income Categories None	<1MW	1-3MW	3-5MW	5-10MW	>10MW	
Central Area	1	-	11	1	1	3	
Northern Area	10	7	22	19	12	9	
Southern Area	49	7	40	26	30	50	
Core Subtotal	60	14	73	46	43	62	
Imm.Periphery	25	6	52	24	25	10	
Int. Periphery	11	2	31	15	6	2	
Other Areas	7	2	22	9	4	2	
Total	103	24	178	94	78	76	553*
	18.6%	4.3%	32.1%	17%	14.1%	13.7%	99.8%

* one case is missing

Two models tested the hypothesis that that income and household location were significantly related. The first model considered four income categories: up to 2MW, from 2MW to 5MW, from 5MW to 10MW and at last more than 10MW. Testing for independence, X2=39.33, with 6 d.f., was highly significant, at 1% level of significance and the independence model was rejected, although some discrepancies were observed.

Then a second model was tested and the last income category was subdivided into three other categories: 10 MW to 15 MW, 15 MW to 20 MW and more than 20 MW. This model was also rejected (X_2=39.56) and fitted well the data as all standard residuals were under the range -2.57 to 2.57, for 1% level of significance. So there is a significant relationship between household location and income distribution.

An uneven distribution of population according to their income was observed, if controlled by the variable sex. If those with no income are considered 71% were female. If the highest income category of more than 10 MW per month is considered, 71% were male against only 29% female.

In respect to the spatial socioeconomic segregation it could be said that if poverty is not totally segregated wealth is, and it is segregated within the Core, especially in the Southern Zone boundaries.

Such a distribution of income and wealth certainly plays an important role in setting activities and establishing who will live where and where which activities will be settled. Also land uses are under the influence of this concentration of wealth.

If jobs are concentrated within the Core as figures from secondary sources have shown (Chapter II), it is expected that a great many trips are generated towards the Core. How does the bus system attend this concentration of demand? How accessible are the services provided?

Table IV shows the distribution of the sampled population according to their housing, work and-or study location.

TABLE IV

SAMPLED POPULATION HOUSING AND JOB-STUDY LOCATIONS

Area	Housing	Work	Study
I- Core	53.9%	56.3%	16.6%
Central Area	3.1%	16.8%	2.7%
Northern Zone	14.3%	13.0%	4.3%
Southern Zone	36.5%	26.5%	9.6%
II- Imm. Periphery	25.8%	16.8%	5.2%
III- Int. Periphery	12.1%	1.8%	1.6%
IV- Other Areas	8.3%	5.2%	1.1%
Total	100%	80.1%	24.5%

Figures from Table IV reinforce how activities are concentrated within the Central Core, being consistent with the figures from the Census which revealed that the Core concentrates 60% of the job market, while the other two peripheries share 20% of the labour market each. It is also important to stress that 80% of the sampled population work while 24% study, which leads to the conclusion that at least 4% work and study simultaneously. These high rates are due to the period during which the survey was carried out in the vehicles, which was weekdays and working hours.

Table V presents a matrix of household and job location. It excludes those who were students, retired or unemployed. At 57%, Southern Zone concentrates the highest percentage of those who live and work there than any other sub area within the Core even if compared with the other aggregated areas. If the Core is considered as a whole, 77% (181 out of 234) of their householders also work there. Immediate Periphery shares the second figure; 30% of their householders also work within its boundaries. Figures for those at Northern Zone are almost 30%. Those who live and work at the same area travel less, and consequently enjoy lower costs, spending relatively less of their earnings on transport.The small figure for Central Area is mainly explained by its land use which is mainly commercial and services.

TABLE V

HOUSING AND JOB LOCATION MATRIX

Household	Job Location						
Location	Cent.	North.	South	Imm.Per	Int.Per	Oth	Total
Central Area	**2**	3	5	3	-	3	16
Northern Area	13	**21**	10	18	2	3	67
Southern Area	35	10	**82**	15	-	7	149
Imm.Periphery	23	23	28	**34**	4	5	117
Int.Periphery	15	10	13	13	**2**	3	56
Other Areas	5	5	9	10	2	**8**	39
Total	93	72	147	93	10	29	**444**

many trips towards this area. Within this area the concentration of public services is observed, including public transport. In the Core Underground Line 1 operates exclusively , as well as a significant amount of Line 2 network. The Core is also served by all the five route types and also the railway system has two main stations there. In fact, transport is trying to attend the supply satisfactorily. By doing so within the Core, maybe the system is not attending peripheral areas as satisfactorily as would be expected. Also it must be taken into account that bus services are mainly operated privately so the system has to be profitable. Whichever service is offered a margin of profitability is guaranteed for the operators, who are mostly private enterprises.

As most of the journeys had work as their main purpose, a model considering the variables housing (1) and work (2) locations and monthly transport costs (3) was tested for independence. From the total sample, 444 weighted cases were considered and were classified into a 3x3x3 contingency table and a hierarchical set of log-linear models was fitted to the contingency table. Using a log-linear model, the number of cases in each cell can be expressed as a function of housing and work location (Core and both peripheries were the categories considered) and monthly costs with transport and any interaction amongst the three variables (Wrigley, N. and Bennett, R.J., 1981). To obtain a linear model, the natural logs of the cell frequencies are used, rather than the actual counts.The best model had the following form:

$$\log_e F_{ijk} = \mu + Y_1(i) + Y_2(j) + Y_3(k) + Y_{13}(ik) + Y_{23}(jk)$$

where,

$F_{ijk}{}^{*}$ = the observed frequency in the cell

μ = the average of the logs of the frequencies in all table cells

$Y_1(i)$ = housing location main effect

$Y_2(j)$ = workplace main effect

$Y_3(k)$ = transport costs main effect

$Y_{13}(ik)$ = two way interaction- housing location and transport cost

$Y_{23}(jk)$\= two way interaction- work location and transport cost

* F_{ijk} is assumed to have a Poison distribution with expected **e** raised to a power which is a function of the explanatory variables considered.

This model presented generating class with only two two-way interactions that were: housing location-monthly cost with transport- $\mathbf{Y_{13}(ik)}$ and work location-monthly cost with transport -$\mathbf{Y_{23}(jk)}$.The absence of the two way interaction between household location and work place- $\mathbf{Y_{12}(ij)}$ could be explained by the fact that the job market is consolidated and concentrated within the Core, and its is independent from Housing location in general. Analysing the standard residuals for this model all values were within the range -2.57 to 2.57 for the 1% level of significance.

When tenure is analysed 59.7% of the sampled population belongs to owner occupier households (it also includes dwellings in squatter settlements) , while 37.9% are tenants and the remaining 2.4% either are missing or belong to other tenure status. Table VI presents tenure according to the spatial distribution of the sampled population.

TABLE VI

TENURE BY HOUSEHOLD LOCATION

Household	Tenure (%)		
Location	Owner Occupier	Tenant	Total
Core	29.76	23.48	53.24
Immediate Periphery	17.56	8.50	26.06
Intermediate Periphery	13.86	6.84	20.70
Total	61.18	38.82	100.0

Although the highest percentage of owner occupiers are located within the core, the same applies to tenants. So no conclusion regarding tenure could be drawn to support the expected concentration of owner occupiers within the Core and tenants in peripheral areas.The ratio between owner occupier and the total was respectively 56%, 67% and 66% for the Core, Immediate Periphery and Intermediate Periphery. Those in the other categories were not considered here.

When tenure was tested for independence according to household location, results yielded a Pearson chi-square, X_2=7.23, with 2 df and the model was not rejected, at 1% level of significance leading to a independent relationship between the variables in concern.

Another way of assessing socioeconomic status is to analyse figures for car ownership. Among the sampled population, approximately 52% of the bus users had a vehicle in their household, but only 19% declared to have access to use of the car, either during weekends or in the evenings; 17% have access to the vehicle occasionally, while 15% have no access to a car at all.

If car owning householders are broken down by housing location a peculiar picture is drawn, reinforcing the conclusion that income and wealth is concentrated and spatially distributed unevenly; 68% of the car owning householders live within the Core Area, 19% in the Immediate Periphery, 8% in the Intermediate Periphery and finally 5% in other areas. These results could also be interpreted as Peripheral areas householders being more dependent on public transport than Core householders. Those with private transport are the ones that happen to live where most of the activities and job market are located.

Testing for independence yields a Pearson chi-square, X_2=29.05, with 2 d.f., leading to a highly significant relationship between car ownership levels and household location. Analysis of the standard residuals showed that the model fits quite well the data, considering a 1% level of significance.

From this section the conclusion is that the Rio de Janeiro population is socially and economically segregated, and that the Core concentrates those with higher educational background and who will have access to the better paid jobs, that consequently allow them to remain living there. The dichotomy is established between Core and Periphery. The circle seems to be reinforcing the trend that for those with a lower level of education access to jobs is constrained, income levels are lower and consequently they cannot afford to live in the Core but in peripheral areas, where access to education and jobs, services and facilities are lacking or constrained.

This spatial and social structure of the city seems to interact and transport services are certainly affected in terms of matching the uneven demand, and consequently the quality of services are also affected and differentiate significantly among the Core and both peripheries. This is analysed next.

V.5.3- Level of Services.

Given the structure of the city, the land use pattern, the distribution of the labour market and finally of the population according to their social status, the level of services and the variation between the core and peripheral areas can be predicted.

It is expected that the bus network would be more dense within the Core than in peripheral areas, that services would be consequently more frequent and reliable there, and that the links between peripheral areas and the Core will offer a poorer service, in comparison to those services run exclusively within the Core. But how uneven are the services provision and are these differences significant among the three areas under study? Inequalities can be considered from two different perspectives. The physical one is related to the way the city is structured (land use) and the social one considers the way population is settled according to their incomes. To what extent are the imbalances in the services due to the city structure or to its social distribution pattern? Or both simultaneously?

In this section the analysis is carried out from the demand perspective and the system is evaluated according to the user's travel patterns and some effectiveness measures are tested. Within this category some attributes such as frequency of the services, accessibility, comfort and convenience, safety, and reliability could be considered as qualitative measures, while others such as journey time and operating speed could be taken as operating performances.

Differences in the services provision due to the city structure is expected especially concerning the operating performances such as in-vehicle travel time, as a result of the distances to be covered which are longer for peripheral households. However, no differences would be expected within the quality of services, such as waiting times and accessibility.

Journey time is a general measure of level of service. Travel time is a result of many other partial times, such as walking, waiting and in-vehicle times, that separately translate frequency of the services, accessibility, comfort, convenience and reliability. Level of services and imbalances within the provision of services among different areas are mainly tested considering passengers travel time.

The survey results are supported by a sample size of 554 users, of which 55% were travelling at least five times a week from Mondays to Fridays, 29% use it more than five times a week, and only 16% use it less than five times a week. So 84% of the sampled population are frequent travellers within the system and so the findings are strongly supported by these captive users.

Next the services are evaluated taking into account some of the attributes previously defined in Section V.2.

V.5.3.1- Comfort.

The system is analysed considering mainly operating records of the surveyed routes such as service utilisation in terms of loading ratios, running times and some vehicle characteristics highlighting steps height and interior noise level.

V.5.3.1.1- Loading Ratios.

The implicit goals of a scheduled service is to provide the highest quality of service while using the least amount of resources. Land use and travel patterns concentrate demand temporally and spatially, worsening the match between supply and demand, and consequently comfort conditions. In Rio de Janeiro this imbalance in service provision is very different between wealthy and poor areas, mainly as a result of the established dependency of peripheral areas from the Core especially in terms of journeys for work purposes. Analysis of demand is one of the possible ways of supporting this argument.

So, passengers transported is the variable that is used to test how demand performs within different areas according to land use and income distribution and to establish loading ratios. Intensity of land use is highly related to concentration of income.

Here the total number of passengers carried on a single journey from the route origin to its final destination are being considered. Some load standards or crowding constraints indicate when service schedule or supply should be revised, e.g. the ratio between passengers carried and vehicle seated capacity (loading ratio) that should not exceed 140 per cent during the peak twenty minutes at the maximum load point, or loading ratios should not exceed 100 per cent for base periods and evenings (Fielding, G. op. cit.).

It was observed that local routes as well as diametrical routes (poor area-CBD-wealthy area type of link) have presented a higher passenger turnover, and contrary to this radial routes , which link either poor areas or wealthy areas to CBD and that have the CBD as their final destination have presented lower turnover as a result of their demand behaviour.

Diametrical routes presented a very specific characteristic. This was that they operated as they were a composition of north and south radial routes simultaneously. As a result of this two different demands for this route may be observed; those who have the Core as their destination and those who have the Core as their origin in one same direction.

Loading ratios were grouped into four categories after raw observation of the data. These are; trips carrying less than 50 passengers, from 51 to 100 passengers per trip, from 101 to 150 passengers, and trips that carried more than 150 passengers. Table VII presents the passengers distribution among the five route types.

If one considers that the average seating capacity of the operating vehicles is 46 passengers, and that at least 48% of the trips carry more than 100 passengers each, loading ratios are exceeding 100%, violating the loading threshold. This provides evidence that comfort conditions are being affected and demand is not been matched satisfactorily by supply.

TABLE VII

LOADING RATIOS PER ROUTE TYPE

Route	Passengers categories				
Type	<50	51-100	101-150	>150	
North radial	19	21	11	2	
South radial	3	18	19	5	
Diametrical	-	28	14	12	
North local	5	17	17	10	
South local	-	9	11	7	
Total	27 (12%)	93 (41%)	72 (32%)	36 (16%)	228

When analysing where this imbalance occurs, the conclusion is that links within poorer areas or between poor areas and wealthier areas (North Radial, North Local and Diametrical routes) correspond to respectively 72% and 67% of the trips carrying between 101 and 150 passengers and more than 150 passengers, supporting the argument that routes serving those areas are the least comfortable ones in terms of the measure of crowding defined above.

It is important to stress that links between poor areas and the CBD are not balanced, as during morning peak hours a high flow towards the Core and a low one from the Core and the opposite during the afternoon peak period has been observed.

From previous studies in the North Radial 394 route (Câmara, 1986) it was observed that during the morning peak vehicles would leave Vila Kennedy towards the Core with approximately 80 to 100 passengers, already exceeding official capacity (seated plus standing that is on average 76 passengers per vehicle). After the first two or three stops the bus would reach its maximum feasible capacity (127 passengers), and these passengers would not leave the vehicle before it reached the Core. In these types of routes it is very likely that the loading ratio exceeds the 140% loading standards during or for more than twenty minutes at the maximum load point. At this stage not only comfort conditions are being affected but also safety conditions are being put at risk.

In this respect it is possible to conclude that services within poorer areas or between these areas and the Core are offered at a poorer quality, if compared to local services or services provided within wealthier areas or between them and the Core.

Table VIII presents loading ratios in relation to the periods of observation. It did not seem that general demand is much influenced by peak or off peak periods. Maybe for what was already explained in relation to the North Radial routes, demand concentration towards one direction is compensated by low demand in the opposite direction.

During inter peak periods for this route type demand is lower in both directions.

TABLE VIII

LOADING RATIOS PER PERIOD

Period	Passengers categories			
	<50	51-100	101-150	>150
Morning peak	10	32	25	11
Inter peak	7	36	29	6
Afternoon peak	10	25	18	19
Total	27	93	72	36

It seems appropriate to support the argument of imbalances in demand distribution with some of the gathered data. Two North Radial route types are taken as an example. Figures for passengers carried are shown for the three periods and for the three days of counting, and in the first column the route direction Core-Suburbs(C-S) is shown and in the second column the opposite direction, Suburb-Core (S-C).

Poorer CBD link type demand:

Route 240

Morning peak		Inter peak		Afternoon peak	
C-S	**S-C**	C-S	S-C	**C-S**	S-C
42	**70**	51	52	**60**	40
30	**68**	53	37	**70**	32
23	**76**	62	46	**73**	25

Route 394

Morning peak		Inter peak		Afternoon peak	
C-S	**S-C**	C-S	S-C	**C-S**	S-C
19	**101**	80	85	**46**	*
38	**57**	35	62	**97**	31
25	**107**	10	58	**94**	27

* During this trip there was a breakdown and passengers were then transferred to another vehicle, so figures for passengers were not available. The figures in bold represent the peak direction within each period.

From the figures presented it becomes clear what has been explained about demand distribution between different directions and among different periods of the day. On average, the morning demand towards the Core was 2.7 times the opposite direction demand while in the afternoon figures for demand towards the suburbs were 2.5 times that towards the Core. The demand during inter peak did not present in general any significant trend compared to the peak period ones. Picture I shows a typical trip in the morning peak period in route 394. Most of the standing passengers travel in such conditions for the duration of their journey.

If diametrical routes demand is presented and a similar approach adopted, a quite different picture may be observed. Next, figures for two Diametrical routes are presented. In the first column the direction Southern-Northern (S-N) zone is observed, while in the second one the opposite direction Northern-Southern zone (N-S).

PHOTOGRAPH I - COMMUTERS ON THE 394 ROUTE MORNING PEAK

Poorer CBD Wealthier link type demand:

Route 434

Morning peak		Inter peak		Afternoon peak	
S-N	**N-S**	S-N	N-S	**S-N**	**N-S**
158	**161**	146	107	**180**	**127**
172	**116**	113	62	**159**	**59**
164	**176**	176	92	**160**	**99**

Route 484

Morning peak		Inter peak		Afternoon peak	
S-N	**N-S**	S-N	N-S	**S-N**	**N-S**
75	**110**	93	81	**98**	**83**
73	**64**	63	67	**78**	**69**
74	**61**	76	58	**77**	**83**

Demand does not present significant changes during the day, as it did for the other route type. Land use and population density may explain this demand concentration and distribution in the Diametrical type routes.

V.5.3.1.2- Running Time.

Running time is certainly one of the most crucial aspects of travel that users in Rio de Janeiro face and it differs more significantly among wealthier and poorer areas. The main reason for this is explained by the land use pattern that concentrates within the Core area both higher income groups and most of the jobs opportunities. As a result of this distribution of activities and population, lower income groups, who usually live in peripheral areas, continue to work within the Core. This group travels longer distances and consequently spends more time commuting at relatively higher costs.

One of the main issues to be tackled in any attempt to improve the system and to minimise imbalances in the quality of services has to be running time. Partial times such as walking, waiting and in vehicle times should also be considered in the analyses.

Next, average running time is presented for the fifteen routes surveyed, for the three periods in order to identify any difference that might occur according to routes serving different areas. It is argued that mean running time is strongly influenced by route distance, dwell time and signalised intersections and to a lower extent by parking restrictions on the route, time of the day and direction of travel (Abkowitz M. and Engelstein I., 1983). The same authors have also suggested that running time variation also increases with route length. Table IX presents average running time for the three periods surveyed and also values obtained from secondary sources for a morning peak survey carried out in 1984.

TABLE IX

SURVEYED ROUTES MEAN RUNNING TIME (IN MINUTES)

Route		Period		
number	am		midday	pm
125	39.8	35*	40.8	51.3
127	54.3	50	51.8	64.7
175	149.6	153	152.3	166.6
240	63.5	61	73.3	73.6
261	76.8	72	79.2	76.0
394	64.0	55	60.0	66.7
415	73.5	73	78.2	86.0
434	88.8	69	85.3	98.8
484	52.5	61	58.3	64.6
512	80.6	84	86.7	101.3
574	86.0	83	89.3	93.3
591	88.7	110	104.6	115.0
606	59.0	57	55.0	64.0
634	76.7	79	78.7	85.5
638	70.0	65	70.0	73.3

175, 512, 574 and 591 routes travel time should be divided by two, because they are circular routes.

* values referring to the 1984 survey.

Generally it is observed that afternoon running times are higher than running times in other periods. In terms of analysing running times in relation to comfort it can be concluded that routes operating exclusively within wealthier areas or between these areas and the CBD, on average, presented the lower figures. These are routes 125, 127, 175, 512, 574 and 591 (the last four routes being circular, so their running time could be divided by two). On the other hand the remaining routes operating within poorer areas or between these areas and the CBD have presented higher running times. If comfort is taken from the view of time spent to overcome distance between two points, routes serving wealthier areas support the argument that they are more comfortable than the ones operating in peripheral areas. In other words it can be said that wealthier dwellers spend less of their time travelling no matter for what purpose.

If the impacts that might occur on the frequency of services is analysed, the conclusion is longer running time routes (mainly operating from poor areas to the CBD) are the ones most likely to present higher variation in their running time, consequently affecting headway and the reliability of their services.

V.5.3.1.3- Vehicle Design Characteristics.

From all the physical characteristics of the vehicles in operation analysed, the height of the steps seems to be the one that most affected passengers comfort, independent of the route type. This is especially so for elderly or handicapped passengers and mothers carrying children. Also the design of the turnstiles make difficult the access of passengers in the vehicle. Although this design has been banned, the operators did not remove them as they discourage fare evasion. Picture II shows a general view of an alighting door, picture III details the height of its steps while picture IV shows the design of a typical turnstile.

For boarding doors either three or four steps are found. All the measures considered the length from the road to the vehicle. The first step was, on average, 43.5 cm high. For getting off there are only three steps and the last one was on average 43.9 cm. Both figures are extremely high and cause discomfort. The difficulties passengers face in boarding the vehicles certainly increases dwell time and delays in-vehicle travel time. These figures could be alleviated if drivers stopped closer to the curb, but this seldom occurs. All the measurements were taken either at the route origin or at their final destination on the 228 vehicles surveyed.

From these figures it is concluded that the quality of services are significantly affected by inappropriate vehicle design characteristics, worsened by poor driving.

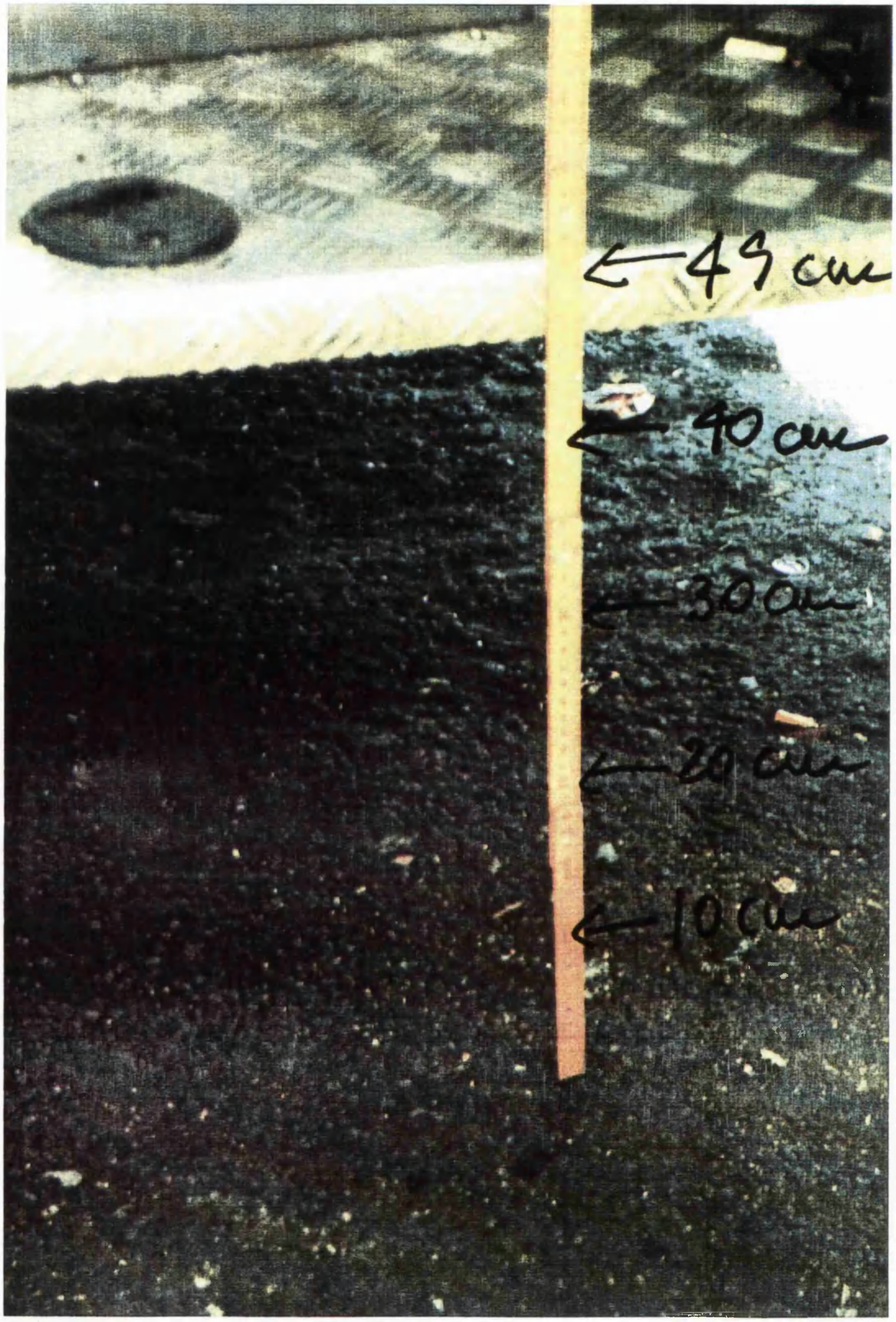
V.5.3.1.4- Noise Level.

Significant work stress does exist for bus drivers as an occupational group, and they can affect the crew's mental health and their job satisfaction. Traffic congestion, peak running times, risk of assault and also money handling were the main stress factors found in the survey carried out among 376 male bus drivers in a major UK city (Duffy C. A. and Mcggodrick A. E. 1990).

Driver behaviour in traffic and against passengers in Rio de Janeiro is very peculiar. When working conditions are considered from vehicle

PHOTOGRAPH II - GENERAL VIEW OF AN ALIGHTING DOOR

PHOTOGRAPH III - DETAILED VIEW OF AN ALIGHTING DOOR



PHOTOGRAPH IV - DETAILED VIEW OF THE TURNSTILE

design, noise level exposure and high temperatures and the lack of facilities at bus terminals such as toilets, it is concluded that any human being subjected to such adverse working environment, plus the stresses inherent to the occupation mentioned above, would by no means behave differently.

During the on-board interview period, it was observed that noise levels were considerable high, independent of the route type or the area where services were being provided. After the conclusion of the on-board survey a noise level counting was then carried out.

The counts took place on two routes that were previously surveyed, routes 415 and 125, diametrical and south radial routes respectively, because they operate two different types of vehicles concerning the location of the motor. While the first one was a front engined type located beside the driver's seat, the second route vehicle's motor was located in the middle part of it. Picture V shows the motor location in a typical vehicle. It was expected that differences would probably occur in the counting. The counting aimed at measuring the level of noise drivers and passengers are subjected to and at drawing some conclusions regarding comfort conditions.

The instrument used in the counting was a sound level meter type 2205, from Brüel and Kjaer. The measurements were taken on the counting type called "fast". The methodology adopted concerned consecutive measurements every one minute during the trip and the instrument was located close to the driver, to measure as accurately as possible the noise level that he was subjected to. Two trips were carried out for each route, with this purpose, on the 16th of November.

The results were quite high for both routes, although the vehicles with the motor located at the rear presented slightly lower figures. Although the results of this noise level counting are limited by the small number of counts, the results could certainly be extrapolated to the system as a whole, as the two vehicle-types were considered typical of the bus fleet currently in operation.

Background noise levels before vehicles started were respectively 70 dB(A) for both counts at route 125, and 62 dB (A) and 64 dB (A) for route 415 counts.

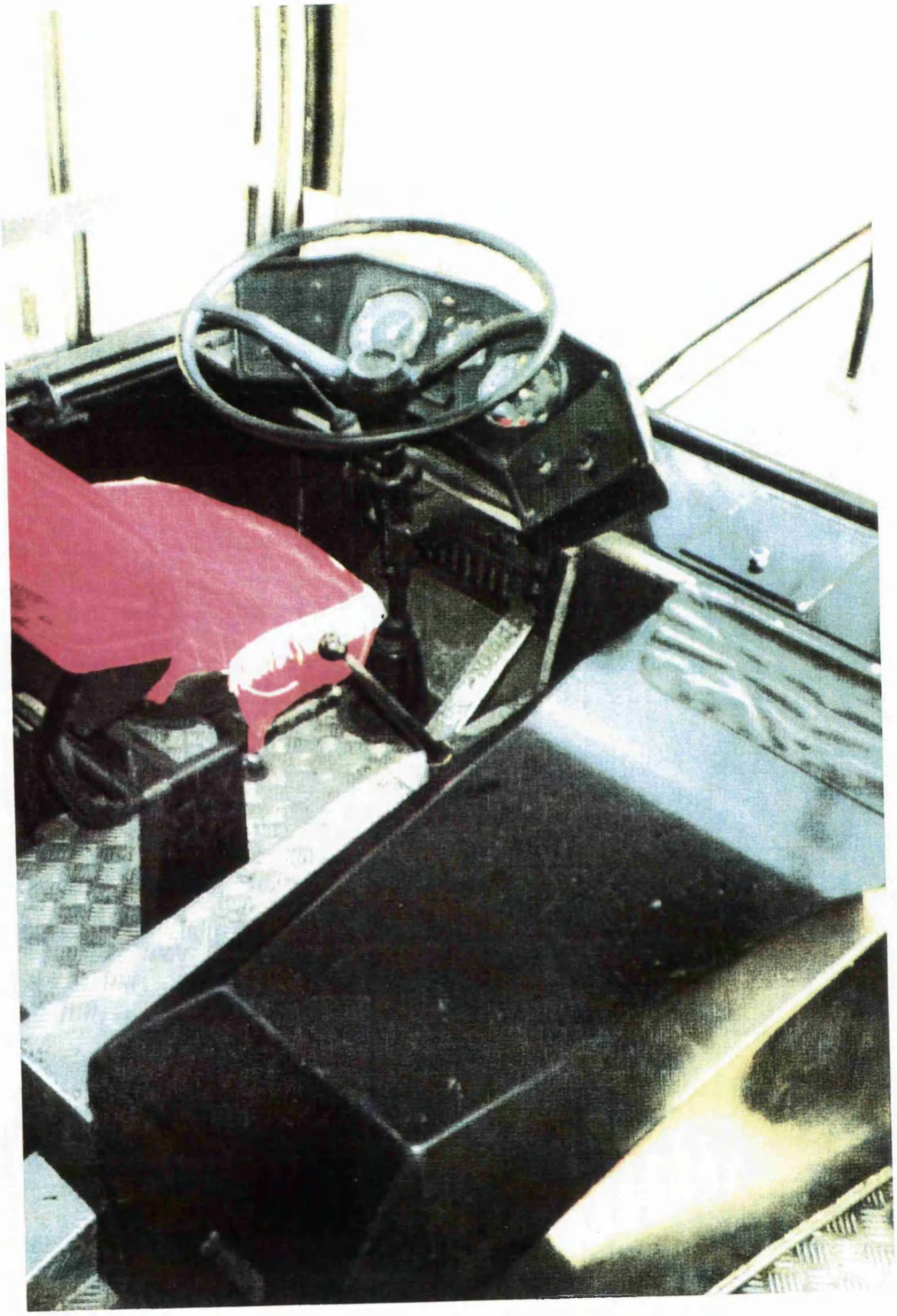
Two different situations were observed with quite significant differences in the noise level results that were when the vehicle was stopped and when the vehicle was in motion. The minimum and maximum values correspond to these two extreme situations, while intermediate values to acceleration and deceleration. Table X presents average noise level results, as well as maximum and minimum values.

TABLE X

NOISE LEVEL COUNTING RESULTS

Route Number	Average Noise Level in dB(A)	Range
125- counts 1	74,53	66-84
125- counts 2	76,04	66-84
415- counts 1	83,02	72-90
415- counts 2	80,08	66-87

PHOTOGRAPH V - VIEW OF THE MOTOR LOCATION



Along a high speed corridor where both routes operate it was observed that while the middle motor vehicle achieved averages of 78 and 82.3 dB(A), respectively for each count, the front motor vehicle achieved figures as 89.6 and 85 dB(A). These counts lasted for six consecutive minutes each.

Some activities that exposure employees to high temperatures or high noise levels are controlled and some limits have to be respected. Concerning noise level the maximum daily exposure to noise will depend upon its level. To an exposure of 85 dB(A), a maximum exposure of 8 hours is established, and if noise levels achieve 90 dB(A), daily exposure drops to a maximum of four hours daily.

What is interesting to note is that drivers and passengers are subjected to such high levels of noise. If drivers are considered, they sometimes drive for more than eight hours a day, and sometimes noise levels achieve figures as high as 90 dB (A), it is expected that over the years some side effects might affect them seriously. They are also subject to high temperature levels, but no measure concerning this variable was carried out.

Drivers's reaction to high levels of heat and noise were examined by Neumann, Romansky and Plummer (1978). The study tested twenty five males aged from 18 to 39 years in a driving simulator, for two hours and 45 minutes each trial, under moderate and high levels of heat and noise; 76^0 F (24^0C) and 55 decibels and 90^0 F (36^0C) and 78 decibels respectively.

A comparison of the subjects task performance, physiology and mood during the two trials revealed significantly high levels of stress under conditions of higher heat and noise levels, as well as decrement on both visual and auditory tasks, manifested elevations in heart rate, systolic and diastolic blood pressures and finally adrenocortical secretion. Moreover, subjective ratings of discomfort and fatigue increased during the second trial.

Drivers exposure to high levels of noise is one of the main stress factors that may affect their health, and endanger their activity. Research studies from Northern Europe have identified bus drivers as a high risk group with regard to coronary heart disease (CHD) mortality. Epidemiological data for a Swedish census in 1981, revealed that they had five times higher CHD mortality than technical, scientific and educational personnel (Holme et. al., 1977, 1980). Norwegian and Danish statistics for the 1970s, again demonstrated the connection between mortality, irregular hours and psychological strain, particularly in respect of shifts, frequent overtime and night work (Denmark Statistics 1979, Duffy C. A. and McGoldrick A. E. op. cit.).

According to a Dutch study, absenteeism, turnover and disability rates also seemed to be higher among city bus drivers in the Netherlands. Absenteeism among these drivers was more than two or three times as high as the national average in general. Bus drivers who had to leave their job for medical reasons did so at younger age than other groups of civil servants. The main conditions leading to disablement related to the back tendons and joints (35%), mental disorders (35%) and cardiovascular diseases (12%). It was also shown that long term absenteeism is a strong precursor of future disability. (Komper et.. al., 1990).

The conclusion from the noise counting is that services are being put severely under threat if the noise level drivers and passengers are subjected to is considered, affecting both their safety and comfort .

V.5.3.2 - Accessibility and Reliability.

These two attributes are tested by analysing users travel time, which is broken down in partial times such as walking, waiting and in-vehicle travel time. Each of these figures separately denotes the degree of accessibility and or reliability occurring within different areas, and consequently among different route types. Other characteristics that measure accessibility are the number of modes taken to realise one journey as well as travel costs.

V.5.3.2.1- Travel Time.

When travel time is considered taking into account users records, an interesting picture provides evidence that travel time is mainly influenced by housing and job location.

If, among many other attributes travel time is taken into account as a general measure of accessibility an interesting pictures is drawn regarding household location.

One interesting way to assess how much commuting may cost, is to multiply a worker hourly rate of pay by the time spent in transport. If a worker spends 48 minutes getting to work in the morning, and another 48 minutes coming back home in the evening , these figures may account for an extra 8 hours a week, or a full working day, for which workers are generally not paid (Gruen, V. 1968).

Table XI presents users travel time in minutes according to their household location. Travel time being considered here includes walking time at both origin and destination and if it is the case at an interchange, waiting time, and finally in-vehicle travel time. Five categories were established after an analyses of the raw data.

TABLE XI

TOTAL TRAVEL TIME BY HOUSEHOLD LOCATION

Household	Total Travel Time Categories (in Min.)					
Location	<30	31-45	46-60	61-75	>75	total
Central Area	8	3	3	1	-	15
Northern Area	15	19	14	14	2	64
Southern Area	60	63	43	22	17	205
Core sub total	83	85	60	37	19	284
Imm. Periphery	19	18	22	24	60	143
Int. Periphery	2	2	10	8	45	67
Other areas	5	3	4	4	30	46
Total	109	108	96	73	154	540*

* 14 missing cases.

Approximately 29% (154 out of 540) of the whole sampled population travel for more than 75 minutes, considering only one way journeys, from which 88% (135 out of 154) live in peripheral areas. Approximately 20% (109 out of 540) travel for less than half an hour, from which 76% live within the Core (83 out of 109). So if the accessibility and travel opportunities ratio is considered, peripheral householders spend more time commuting, severely disrupting their opportunity to take part in different activities in several localities, while Core householders experience higher accessibility in the sense that they spend less of their available time commuting.

Testing total travel time for independence, the model yielded a Pearson chi-square, $X_2=148$, with 4 d.f., leading to a highly significant relationship between the two variables. Total travel time was considered according to the following three categories: trips lasting up to 60 minutes; from 60 to 90 minutes and trips longer than 90 minutes.

Total travel time for those living in the Core was on average 46 minutes, for those living in Immediate Periphery and Intermediate Periphery was respectively, 72 and 96 minutes. All these figures related to one way trips. The conclusions drawn may be that those living in the Core are closer to their jobs, are offered a better service, more alternatives are available, and consequently they travel shorter distances and spend less time commuting. In other words Core householders enjoy higher accessibility to their daily journeys to work and also are offered a more reliable service.

If figures for São Paulo are presented for a comparison, a quite interesting picture may be drawn, considering income levels and commuting time. For those earning less than 4 Minimum Wages per month total travel time is on average two times higher than for those earning more than 30 Minimum Wages per month, providing evidence that lower income groups do also live in peripheral areas, as in Rio de Janeiro (Rolnik, R. et.. al. 1990).

It is interesting to note that walking and waiting times are one of the partial travel times that impact overall total travel time significantly. Total travel time could be written as the following equation;

TT = WKT + WTT + IVT

where,
TT= total travel time;
WKT= walking time;
WTT= waiting time;
IVT= in-vehicle travel time.

While the first variable could be considered a measure of accessibility, the second a measure of frequency of services and reliability, and the third one a measure of operating performance. For the whole sampled population the three partial travel times shared the following percentages;

TT = 20% WKT + 16% WTT + 64% IVT

Analysing these figures it is concluded that 36% of the total travel time is spent either walking or waiting. When these figures are broken down in relative terms by household location, in-vehicle travel time, they did not present any significant changes, varying from 62.1% for those living at Intermediate Periphery and 64.8% for those living at Immediate Periphery. As shown previously, absolute values for total travel time differs significantly among the three areas. So absolute values are substituted in the equation, taking into account the percentage for each area in particular.

Area	TT =	WKT	+ WTT	+ IVT
Core	46 =	10.4	+ 6.4	+ 29.2
Imm. Per.	72 =	12.8	+ 12.5	+ 46.7
Int. Per.	96 =	17.3	+ 19.1	+ 59.6

If walking time (this figure is certainly related to the walking distance) is analysed, it is evident that time increases as the distance from the Core increases, and figures for Intermediate Periphery are 70% higher than the ones for the Core, providing evidence that services are more physically accessible within the Core than they are in Peripheries.

When walking time and household location were tested for independence they yielded a Pearson chi-square X_2=68.05, with 6 df and the model was reject, both variables being clearly related.

Waiting time is even more critical, and those living in Intermediate Periphery wait almost three times longer than those in the Core, showing that services within the Core present a higher frequency and reliability, and also that more alternative routes are available. If waiting times are tested considering both origin and eventually transfer, the model for independence is also rejected (X_2=127.14, 6 df).

If a similar approach for analysing partial travel times is adopted taking into account users travelling time records (in minutes) according to the route types they make use of, figures confirm that within the Core, services are of better quality. Figures are presented in an ascending order, and links are according to routes within wealthy areas, wealthy and CBD, wealthy-CBD-poor, within poor and finally poor and CBD.

Route Type	**TT**	=	**WKT**	+	**WTT**	+	**IVT**
South Local	**42**	=	**9.95**	+	**6.05**	+	**26.00**
South Radial	**53**	=	**10.50**	+	**5.56**	+	**36.94**
Diametrical	**62**	=	**12.95**	+	**8.55**	+	**40.50**
North Local	**68**	=	**14.07**	+	**11.15**	+	**42.78**
North Radial	**92**	=	**15.54**	+	**22.72**	+	**53.74**

Here it becomes more evident how services are differentiated among the three areas under study. If walking time is taken as an example, within wealthier areas figures are on average ten minutes, which seems quite reasonable; five minutes at both origin and destination. For diametrical route users figures are slightly higher; 13 minutes, while for North type route users, walking times reached average values of 15 minutes. These figures are closely related to the city structure and the density of the network. At this step the accessibility of services are being assessed and figures could not be different as network extension is denser within the Core than in peripheral areas.

Waiting time is the most crucial among the three partial travel times and the one most related to social inequalities. While south type route users face an average waiting time of five minutes, in the other extreme North Radial route type users wait, on average, for more than twenty minutes. Diametrical and North Local type routes users wait longer for the bus than the southern type, they are far from waiting for the bus as long as North Radial route type users do.

In-vehicle time differences were expected to be higher for those links between peripheral and central areas, and are explained by land use patterns. Even if a service with similar reliability was provided among the five route types, no significant changes would be possible regarding in-vehicle travel time, due to the different distances each route type may overcome.

Initially these figures are very important in raising issues related to services frequency and later to consider them as measurements of how unreliable services within poorer areas may be.

V.5.3.2.2- Transfers.

Accessibility could also be measured in relation to the number of modes a passenger may use to travel from his origin to his destination. As a result of the city structure a denser network within the Core is expected, consequently fewer transfers. If more transfers are necessary accessibility is poorer. The aim of measuring the number of modes that might be taken is to detect to what extent accessibility is poorer in peripheral areas. Table XII presents the number of modes utilised for one single journey, taking into account household location.

TABLE XII

NUMBER OF MODES BY HOUSEHOLD LOCATION

Household	Number of Modes			
Location	One	Two	Three	Total
Central Area	15	2	-	17
Northern Area	63	16	-	79
Southern Area	186	16	-	202
Core sub total	264	34	-	298
Imm. Periphery	89	52	2	143
Int. Periphery	38	23	6	67
Other Areas	10	21	15	46
Total	401	130	23	554
	(72%)	(24%)	(4%)	(100%)

It is also clear that those living within the Core have a higher accessibility and are able to travel making fewer interchanges because their destination is closer to their home and also because there are more routes or modes available. It is not by chance that 76% of those who interchange using two modes live in peripheral areas, and all of those who use three modes also live within peripheries.

Testing transfers (considering only two categories, interchange and non interchange) and household location for independence, the model yielded a Pearson chi-square X_2=97.07 with 2 df, leading to a clear relationship between household location and accessibility. The model fitted the data quite well.

For those 153 users that interchange, 80% use other bus routes, 4,5% the underground, 4,5% the train, 4,5% another bus and the boat, 3,2% other modes, and finally 1,3% the boat (2% were missing).

As fares are proportional to the trip length, and there is no integrated fare system, it is evident that those living in Peripheral areas will pay higher fares for two simple reasons; they travel longer distances and they are the ones more likely to interchange. Consequently they face lower access to the system in financial terms, as well as they are constrained to use the transport facilities that might be available .

V.5.3.2.3- Travel Costs.

Travel costs is another important issue that deserves attention if any attempt to improve the system is considered, mainly in terms of making the system more accessible to lower income groups, as costs in travelling can represent a constraint for them.

Fares are variable and charged in proportion to the route length. In this way it is clear that those living in peripheral areas are the ones that are likely to pay higher fares in absolute terms and in relative terms, their cost are even higher as their income level on average is lower than the income of those groups living in the Core.

Travel costs are also increased for those peripheral users as they are the ones more likely to interchange and, as there is no integrated fare scheme. When they interchange, they also must pay another fare.

Table XIII shows daily travel costs, according to household location. Travel costs are considered here on a daily basis, and four categories were considered, taking into account number of fares paid; up to 2 fares, from 2 to 4 fares, from 4 to 6 fares and finally more than 6 fares a day. The fare value for calculations corresponded to a single category III fare, which was the most common among all the surveyed routes, and that happened to be CZ$0.88 for almost all the period the survey was carried out (October 1989).

TABLE XIII

DAILY MONETARY TRANSPORT COSTS BY HOUSEHOLD LOCATION

Household	Daily Cost (fare category III)				
Location	<2	2 to 4	4 to 6	>6	total
Central Area	10	2	2	3	17
Northern Zone	31	29	12	7	79
Southern Zone	100	58	12	32	202
Core Sub total	141	89	26	42	298
Immediate Periphery	45	43	26	29	143
Intermediate Periphery	9	16	23	19	67
Other Areas	2	6	8	30	46
Total	197	154	83	120	554

Figures from Table XIII show that only 36% (197 out of 554) of the whole sampled population pay up to two fares a day; one bus each way. From this figure 71% live within the Core. If at another extreme it is analysed where those spending more than six fares a day live, it is found that 65% (78 out of 120) of them live in peripheral areas, as well as 68% (57 out of 83) of those spending between 4 and 6 fares a day.

The model which tested for independence the variables household location and monthly transportation costs was rejected as yielded a Pearson chi-square X_2=91.76 with 6 df, leading to a clear relationship between the two variables. The model categorised transportation costs as follows; up to 36.00 Cruzados a month; from 36.00 to 72.00; from 36.00 to 108.00 and at last more than 108.00 Cruzados. Checking the standard residuals the model fits the data reasonably well. The model of independence also tested workplace and transportation costs, and it was also rejected as it yielded a Pearson chi-square, X_2=33.74 with 6 df. The model also fitted the data reasonably well.

Another way of assessing monetary travel costs is to consider the percentage of the income allocated to transport according to household location. Four categories for relative costs in transport were considered: up to 6%, from 6% to 14%, from 14% to 20% and more than 20%. Table XIV presents relative costs in transportation according to housing location.

From the 444 users considered approximately 50% (225 out of 444) spent up to the maximum amount the Government suggests should be apportioned to transport, that is 6%, from which 65% (147 out of

225) live in the Core. The two following categories have presented a fair distribution among the three areas, but if the last one is considered 63% (41 out of 65) of those with 20% or more of their earnings spent on transport live in peripheral areas. This means that peripheral householders are the ones that face the highest relative costs of transport in Rio de Janeiro.

TABLE XIV

RELATIVE MONETARY COSTS IN TRANSPORT BY HOUSEHOLD LOCATION

Housing	Percentage of Income Allocated				
Location	<6%	6% -14%	14%-20%	>20%	
Core	147	48	14	24	
Immediate Periphery	58	33	12	14	
Intermediate Periphery	20	35	12	27	
Total	225	116	38	65	444*

* Students, unemployed and retired were not considered.

When relative monetary costs in transport (according to the following categories:up to 14%; from 14% to 20% and more than 20%, is tested for independence against household location) the model yielded a Pearson chi-square X_2=27.39 with 4 d.f., and it is rejected, leading to a significant relationship between the two variables.

V.5.3.3- Qualitative Evaluation.

In the survey two qualitative evaluations were carried out, the first one by the interviewers (technical sheet- first page of the questionnaire) and the second one by the users. It is important to be aware that the findings relating to this qualitative evaluation may be casual and may not necessarily represent a permanent picture of the system, especially the one considered by the interviewers.

The technical sheet included some attributes such as vehicle hygiene and maintenance, traffic conditions, driver, conductor and passenger behaviour. A five range scale was considered for the evaluation; very good, good, fair, bad and poor. In Appendix XI the results from the transport experts' point of view is presented.

Concerning hygiene and maintenance, only 33% of the vehicles surveyed were rated under very good or good . Items such as interior cleanliness, conditions of seats, tyres and graffiti were observed, as well as vehicle exterior conditions. Among all the vehicles surveyed the ones serving route 261, operated by CTC-RJ were in very poor condition; holes were found in the vehicles' floors, windows were falling apart and also high vibration levels were observed.

Concerning traffic conditions, none of the trips carried out was rated under very good traffic conditions, while only 28% at good conditions. Basically considered here were traffic flows and any unexpected incident that might occur such as accident or breakdown. It is also worth noting that 30% of the trips were made under bad or poor traffic conditions.

The next three attributes relate to behaviour, considering the three actors directly involved in the service, two of them as providers; drivers (D) and conductors (C), and the last one as consumers, the users (U).

It is important to make some comments not only on the results but also on the criteria by which behaviour was rated. Behaviour was mainly related to inter personal relation among the three actors involved on the service. Drivers as the most active actor was the one that acted and reacted more directly, such as breaking the vehicle suddenly and deliberately, not stopping at the bus stops either to collect or to drop passengers, not respecting traffic lights. These were among the most common misbehaviour observed.

In this respect (not trying to justify it, but to understand it) it was observed that work conditions for both drivers and conductors were very precarious, especially for the driver. There were no toilet facilities at the final stops, drivers were subjected to high noise levels for long periods as the counts have shown, worsened by heavy traffic conditions, high temperatures (as motors were mostly located at their side), and finally the long working hours. It is believed that over the years all these adverse working conditions may affect their health seriously and irreversibly and may explain partially the way they behave. Although they are liable to punishment and fines from their employers, it does not seem to alleviate nor solve the problem.

Behaviour concerning conductors are more related to their direct relation with passengers and the problem of change, which usually provokes arguments between passengers and conductors, as some fares are charged at a value that is difficult to give change. Most of the problems occur when for some reason passengers demand their change and conductors do not have the money for it.

Passenger behaviour is concerned with their relation with drivers, conductors and themselves. Usually passengers tend to be very arrogant because they are paying for the service and then they demand attention, respect and consideration. Drivers tend to be blamed if traffic is bad, if any accident happens. Usually they want to reach their destination as quickly as possible, no matter what is in the way. After defining how behaviour was considered for each actor in particular, some comments regarding the results are given.

So it is not by chance that from the interviewers perspective drivers were so badly rated; 20% had a bad or poor behaviour while driving the vehicles. Conductors have behaved quite well in comparison to drivers as well as passengers. At the users' questionnaire drivers and conductors are also evaluated from a different point of view.

During the on-board interviews users were asked to rate some of the system characteristics and attributes, in accordance to a scale that ranged from very good or very high to very poor or very low, considering three intermediate values, good-high , fair and bad-low. The attributes evaluated were cleanliness, comfort, reliability, service conductors behaviour, fare level, assault risk, and safety. Table XV presents the results of this evaluation in a summary way.

TABLE XV

BUS USERS EVALUATION

Attributes	Scale (in percentage)				
	Very good	good	fair	bad	poor
Cleanliness	0.5	16	47	22	13
Comfort	0.9	15	41	23	19
Reliability	1.2	25	30	22	22
Day frequency	6	48	24	14	8
Evening frequency	1.3	12	27	34	27
Weekend frequency	0.5	10	29	30	31
Drivers behaviour	1.3	22	31	22	24
	Very high	high	fair	low	very low
Fare level	15	41	41	3	.2
Assault risk	27	38	19	15	.4
Safety	.6	14	40	34	13

From the figures from Table XV it appears that users are not very satisfied with the services provided. Comfort conditions were rated as good or very good by only 16% of them, although 77,3% have declared that they usually travel seated, 11% standing, while 12% both seated and standing. These figures could be biased by the fact that all passengers interviewed were travelling seated. The same figure applies for cleanliness.

Concerning reliability, 44% agreed that services are bad or poor. Service frequencies fall considerably from day to evening and at weekends. Driver behaviour was rated very good or good by only 23% of the users. Fares were considered high or very high by 56% of bus users, while 55% considered the risk of being assaulted high or very high. It is not by chance that when they were asked about previous experience of assaults in the bus, 17% have already experienced a personal attack while using the system, 18 % have seen others being assaulted, and 7% have seen and been assaulted. The routes that users rated as the more dangerous ones where those operating within the Core, where the contrast of classes was more evident. In 1989 20 to 25 robberies of the fare box were registered on the Rio de Janeiro's bus system, not including mugging. Almost 50% rated the services as not being safe enough. Safety here was considered in relation to traffic and the way drivers behave.

When users were asked to suggest measures that in their opinion would improve the quality of the services, 42% agreed that more buses should operate in the system. When these figures are analysed considering housing location , while only 28% of Core households were positive about it, figures for Immediate and Intermediate households rose to 53% and 72%, respectively, providing evidence that demand was poorly matched by supply within these peripheral areas.

For 50.4% of the total passengers, the crew should be better trained, but significant differences were observed considering housing location;

58% of the Core households wished a better trained crew, while respectively 40% and 36% of Immediate and Intermediate Peripheries households did so. These figures are important to reveal how passengers perceptions may vary according to their socioeconomic background (for higher income groups a better trained crew seemed to be more important, than for those in lower income categories).

A better vehicle maintenance was desired by 20% of the users, with no significant differences according to their housing location. Finally, 23% suggested that fleet should be renewed and 19% suggested that a schedule for the services provided should be adopted.

Surprisingly when they were asked about willingness to pay more if services were improved, 74% were positive about it, independent of their housing location, while the remaining 26% were very strong in their negative position, saying that the system was already far too expensive for the poor services they were offered.

From the sample 51% were bus users only, while other modes were eventually used by the remaining 49%, such as the underground by 33%, the boat by 5%, the train by 3%, and the train, the underground and the boat simultaneously by 7%.

When those who used modes other than the bus were asked to select the one which provided the best service, 78% rated the underground as providing the best service, mainly because of the comfort offered, air conditioning, higher speed, cleanliness, and safety concerning both the absence of traffic and less risk of assault, as well as the most reliable service; the second higher rated mode was the proper bus and the reason was the network extension and density and more alternatives, followed by the boat because its reliability and scheduled services offered and at lastly the train, because of its speed.

From the total sample, 81% had either an alternative bus route or even another mode of transportation, while 17% did not have any alternative to the route surveyed and 2% did not know if there was another way of doing that trip. The attributes for those who had an alternative to choose the route surveyed is presented in the Table XVI. They are exclusive one from the other.

TABLE XVI

USERS ATTRIBUTES SELECTING CRITERIA

Attributes	Yes	No
Wait time	38%	62%
Walk time	25%	75%
Speed	24%	76%
Comfort	19%	81%
Fare level	12%	88%

It is interesting to notice that the most significant attribute for selecting the route was the shorter wait. As stated previously, waiting time is related to service reliability and frequency. And results reinforce findings that service reliability is an important attribute for users in their decision making process.

The second attribute in importance is walking time or walking distance to the stop. For 25% of the sampled population this was decisive in opting for the selected route. Again results seem consistent to the findings of Wachs (op. cit.).

Speed was also considered by almost one quarter of the bus users in selecting their route. Other attributes such as non interchange, fare levels, and safety were not considered by most of the bus users as a criterion for selecting the travelled route. It could be concluded that users have rated time as the most important attribute for selecting the route they have travelled taking into account waiting, walking times and in-vehicle travel time.

V.6- CONCLUSION.

From the analysis presented in this Chapter it was possible to support both of the hypotheses raised previously, namely that space is socially and economically stratified and that transport services are more inequitably distributed between the wealthier and the poorer areas than would be expected.

These findings seem to be strongly supported by Lynch (1981), who says that racial and class segregation not only prevents social mobility and communication, but also promotes inequalities of opportunity and services. He also argues that inequities of access are likely to increase with spatial segregation.

A city with the size and complexity of Rio de Janeiro would not be expected to provide an equitable transport system throughout the city, but at least some minimum thresholds of equality within the system in order to guarantee a certain level of service among different areas and to assure that inequalities do not become too discrepant may be expected.

The socioeconomic distribution of the population, and the city structure; land use presents a main Core that centralises not only services and labour market, but also all sorts of facilities. In addition, higher income groups settle there, conversely the peripheries lack services and concentrates lower income groups, and this leads to a dependency of those living in peripheral areas on the well serviced Core. This was clearly identified when the matrix of housing and work location was presented.

Public service provisions are of lower standard within Peripheries and from the Peripheries to the Core as a consequence of this physical pattern of distribution of activities as well as social distribution of the population.

Transport is one among many other public services to be seriously affected by the way activities are distributed and population settled. In the Rio de Janeiro core-periphery model, most of the trips generated had the Core as their main destination, especially for work purposes. Consequently transport demand is concentrated in space and in time, and supply seems not to cope satisfactorily with this concentration of demand.

This physical and social pattern of distribution sets up some constraints for those living in peripheral areas who depend on the Core, and have to travel longer distances either to go to work or to reach facilities, consequently leading to higher travel times, higher costs in absolute terms and even higher costs in relative terms (if individual earnings are considered), lower accessibility and finally a less reliable and comfortable services. Although peripheral lower income householders tend to value time and costs differently than those core higher income groups, and housing location is a threshold between housing prices and transport costs, this fact does not exclude the effects of the constraints cited above.

These constraints are not unexpected and are mainly explained by the physical component that is the distance that separates the dependent Periphery from the independent Core. Distance explains not only some quantitative factors of travel, like time and costs, but also some qualitative ones such as the frequency of services, reliability, crowding, comfort etc..

This spatial structure of the city plays a decisive role in determining some of the trip pattern characteristics, such as the type of links. In the Rio de Janeiro case, the periphery-core movement is the main one.

If total travel time is analysed as a composition of some component times such as walking at the origin, waiting at the stop , in-vehicle time, transfer time (when no direct services are available), and finally walking time at the destination, it would be expected that the further a person lives from the Core, the longer the total travel time will be.

Variations in some of these components of travel times are likely to occur according to the area in which services are provided or the type of link. These include in-vehicle travel time which is due to the distance factor, walking times that are a result of the network density; but no differences should be expected in others such as waiting time, if services were more evenly distributed.

It is clear that as a consequence of longer distances to overcome, in-vehicle travel time is going to be higher for those living in peripheral areas, no matter how frequent or reliable services are. In-vehicle travel times do not depend on the quality of the service offered, but it is inherent to the structure of the city, traffic volumes, dwell times, and generally is proportional to the distance travelled.

In fact, among the sampled population, in-vehicle travel times for those living in Immediate and Intermediate Peripheries were highly proportional to the distance from the Core, and were respectively 60% and 104% higher than the the in-vehicle travel time of those living within the Core.

Similar to in-vehicle travel time, walking times have also presented significantly variations and higher values for those peripheral commuters, due to network density which is higher in the Core. It is clear from these results that the accessibility of peripheral areas is also worsened by longer walking distances.

When waiting time is considered it is not expected that such significant differences would occur, as this component of travel time is not related to the structure of the city, but to the frequency of services operated and to their reliability. It is very important to stress here that waiting time is not necessarily related to the route headway, because sometimes passengers do not board the first bus, but the second or even the third one. Waiting is also subjected to the crowding of the vehicles and comfort conditions. It was shown that loading factors from peripheral areas to the core achieved high ratios, in comparison to routes operated within the core. This variable presented the most crucial differences among the different areas of concern, and Peripheral dwellers actually faced waiting three times longer than Core dwellers, providing evidence that services are in fact unevenly distributed.

These imbalances within the system seem to be the most crucial factors that reinforce social segregation and hence constrain access to opportunities of those less well off, who live in the peripheral areas.

Reliability of the services, crowding and comfort are the attributes that produce most fluctuation within the system according to the socioeconomic status of the population and the ones that affected them the most.

Travel costs is the other factor that presents significant variations among different socioeconomic groups. Peripheral areas householders are the ones more likely to make transfers and fares are charged proportional to the distance travelled and the number of transfers, as there is no fare integration system within the bus mode or between this one and other public modes of transportation. So travelling in a second mode means paying another fare.

The level of services of the bus system in Rio de Janeiro is then strongly influenced by the city's physical structure that establishes trip chains, travel times and costs and compromises the quality of the services provided significantly.

Parallel to this physical structure, a social structure is observed, in terms of class segmentation within the space. If a gradient of income and distance is considered, it is observed that income levels decrease as distances from the core increases.

As a result of both the physical and the social structure, it may be concluded that lower income groups are the ones more affected by the transport system. In other words, it may be said that the wealthier areas are provided with a better service to the detriment of poorer areas.

Chapter VI presents how these variables, distance, travel times are related and where the most crucial differences occur, aiming at setting up some alternatives that could improve the quality of the services offered which is presented in Chapter VII.

CHAPTER VI- CAUSAL ANALYSIS

VI.1- INTRODUCTION.

Analysis from the two preceding chapters allows some conclusions to be drawn regarding the bus service provision among different areas in Rio de Janeiro.

Imbalances within the system were crucial and two extreme situations were identified; (i) links between peripheral areas and the Core, mostly utilised by lower income groups offer a service of much poorer quality; (ii) links within the proper Core, mostly used by higher income groups, offer a much better service.

The following attributes were identified as the most crucial ones; accessibility, reliability and comfort (Chapter V). These factors seemed to differ most significantly between the three areas of concern; Core, Immediate and Intermediate Peripheries.

Accessibility was mainly measured by variables such as travel time considering all the components times, such as walking, waiting and in-vehicle times, number of transfers and travel costs; reliability by some partial travel times such as waiting time; and finally comfort by loading ratios.

This Chapter analyses these crucial elements which differed most significantly between wealthier and poorer areas, in order to identify the reasons for such variations, and also to establish a scale of importance between them. The aim is to set the possible policy measures that could be taken to tackle the most critical differences and to minimise the degree of these imbalances.

In this chapter total travel time and its constituent parts, absolute and relative travel costs and crowding ratios are the three variables selected for further investigation. Most of the variations observed are expected to occur on one hand due to the spatial component- distance between housing and job location, and on the other due to imbalances between supply and demand and also congestion.

From the study area, three concentrical spatial areas have been previously defined: Core (1), Immediate Periphery (2) and Intermediate Periphery (3). Those individuals who lived in any other area than these three were excluded from the following analyses.

A nine cell matrix considering these three areas was built up and the rows are determined by the the housing location, the columns either by the working or study places. In doing so those who use the system on a regular basis are being selected, so the findings are significant.

The purpose of this matrix is not only to support the argument that the level of services within wealthier areas are of much better quality than would be expected in comparison to services operating within peripheral areas and from the fringes of the city towards the Core, but also to identify and explain the reasons why they are occurring. In doing so, it will enable the establishment of appropriate measures to minimise these imbalances.

Three hypothesis will be tested;

1- Figures are expected to increase towards the peripheral areas, due to longer distances. Also within each row it is expected that the lowest figures will also belong to the matrix diagonal because of shorter journey distances.

2- The same would apply for the diagonal cells, which represents those individual that live and work within the same area. It is expected that diagonal values would increase towards the peripheral areas and achieve the lowest figures in their respective rows, as distances are likely to be shorter in comparison to links with any of the other two areas.

3- Correspondent cells (symmetric ones) in the matrix are expected to present similar figures as journey length and travel time to and from the considered areas should be the same, especially if services operate satisfactorily and no significant imbalance is observed.

The selected variables are analysed according to the housing and working-study location matrix. The analysis is carried out in a comparative basis and each of the variables identified previously as the most important ones are tested separately.

Table I presents a matrix of distribution of the sampled population according to their housing and job or study location.

TABLE I

HOUSING AND WORK-STUDY LOCATION MATRIX- FREQUENCIES

	WORK- STUDY PLACE			
HOUSING	Core	Imm.Periphery	Int.Periphery	Total
Core	247	42	2*	291
Imm.Periphery	94	57	6*	157
Int.Periphery	43	13*	9*	65
Total	384	112	17	513**

* Small sample sizes. Any inference considering these figures are to be taken with caution.

** 41 individuals living in other areas were not included here.

Unfortunately the Intermediate Periphery does not attract sufficient number of people who live in the other two areas and that either work or study there, to support any comparison between symmetric cells. But this evidence on the other hand, supports the argument that the Intermediate Periphery householders are extremely dependent on the Core or Immediate Periphery either for work or study.

Total travel time is presented first, and then components of travel time, such as walking, waiting and in-vehicle time, followed by incidence of transfers, travel costs and finally comfort conditions. Comfort conditions is defined by the the percentage of those who have declared to always travel seated.

VI.2- TOTAL TRAVEL TIME.

Total travel time is being considered users travel time form their origin to their destination, comprising all components of their travel time; walking, waiting, transfers when appropriate and finally in-vehicle travel times. These figures correspond only to one way of travelling, being possible to assume approximately the double for total daily commuting time.

Total travel time is not only a function of characteristics of the journey such as the distance to be overcome, access and egress times, in-vehicle time, waiting times but also of congestion and demand flows that certainly play an important role in setting up total travel time.

Traffic conditions affect operating speed and consequently increase in-vehicle travel time. Demand flows may constrain users access to the first vehicle, increasing their waiting times as well as increasing dwell time.

Table II presents users total travel time according to the nine cell matrix. Total travel time is being considered only for one way and it is not total daily time spent on transport. If only influenced by distance, total travel matrix would be approximately a symmetric one, with the travel times to and from zone pairs being similar. This does not occur in some of the pairs.

TABLE II

TOTAL TRAVEL TIME VARIATION (in minutes)

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	45	72	83*
Imm. Periphery	80	67	83*
Int.Periphery	108	85*	77*

* Any conclusion regarding these figures are to be considered carefully, because their sample sizes are not significant.

If the time spent for all those who work or study in the Core according to their Housing location is compared, two ratios could be established according to a gradient of distance from the Core, between both Peripheries' householders total travel time and the Core householders total travel time. These ratios, in the first column, are O_{31}-O_{11}=2.4 and O_{21}-O_{11}=1.8, showing an increase of 61% for the first gradient and 104% for the second gradient. The ratio between both peripheries is O_{31}-O_{21}=1.35. Figures in the first row also presented an increase towards both peripheries and respective ratios are O_{13}-O_{11}=1.85, O_{12}-O_{11}=1.60 and O_{13}-O_{12}=1.15. So here hypothesis 1 is totally supported.

If a similar approach is adopted for the trips made within one area, the following ratios are observed; O_{22}-O_{11}=1.48, showing that trips within the Immediate Periphery are on average 48% longer than the ones within the Core and O_{33}-O_{11}=1.7, providing evidence that trips within Intermediate Periphery are 70% longer than those within the Core, supporting hypothesis 2.

Both symmetric cells O_{21}-O_{12} and O_{23}-O_{32} presented ratios very close to one, respectively 1.11 and 1.02, but not the cells corresponding to the link between the Core and Intermediate Periphery which presented a ratio of 1.30, providing evidence that the direction of the trip may lead to higher flows of demand as well as more congestion, both of which may lead to a significant increase in total travel time. Here hypothesis 3 has not been totally supported, providing evidence that some inequalities occur.

What are the explanation of such variations if the distance between the links are approximately the same?

If the link between Intermediate Periphery and the Core is analysed, taking into account both of the directions, it is observed that the one towards the Core takes on average 25 minutes more than in the opposite direction or has a 30% longer travel time. This can be explained by the fact that those who live in the Intermediate Periphery and work in the Core travel with the heavy traffic flow, while those who live in the Core and travel in the opposite direction do so against the flow, saving them some time. If this figure is multiplied by two, it may be said that peripheral householders spent daily, on average, almost an extra hour commuting, than those who travel approximately the same distance in the opposite direction. So total travel time is certainly influenced by the direction of the trip due to traffic and demand flows that to some extent may explain congestion.

If the link between the Core and Intermediate Periphery is taken, it is realised that those who live in the Intermediate Periphery and work in the Core travel almost two times more than those who both live and work in the Core. Here travel time is explained mainly by journey distance, frequency of the services and alternative routes or modes .

If operating speed is analysed, it is observed that figures against the traffic flow among the three routes surveyed in the link between the Core and Intermediate Periphery were 32%, 21% and 35% higher than with the flow. Consequently travel time between the Core and Periphery is definitely influenced by the direction of the trip. Congestion is more likely to occur in the morning peak period towards the Core and in the afternoon peak in the opposite direction.

The reason for these imbalances in travel time may be explained by the concentration of job opportunities within the Core (it was seen in Chapter II that the Core concentrates 60% of the labour market while only 40% of the active population) and labour force in peripheral areas. So the Core acts as a pole of trip attraction and Peripheral areas as a pole of trip generation.

This pattern of labour market and active population location leads to a concentration of the demand, and the transport system does not seem able to cater for such a high flow of passengers towards the Core in the morning and back to the Peripheries in the afternoon.

So the links between the Intermediate Periphery and the Core and between both peripheries are the ones that deserve further attention as their values have differed more apparently.

It seems that travel time is also strongly affected by the direction of the travel and not only by the journey length. The direction of the travel is in turn also influenced by the concentration of demand and by traffic flows, consequently increasing overall travel time.

The concentration of the demand may impact total travel time, especially if the possibility of users not being able to board the first vehicle is considered, which in turn increases their waiting time. Also higher demand will lead to longer dwell times, and this certainly increases in-vehicle travel time. Both of these components of total travel time are clearly related to the balance between demand and supply.

At this stage it seems that it cannot be unravelled to what extent variations in total travel time are due to congestion, or to imbalances between supply and demand.

For this reason the next steps will analyse the three components of total travel time to identify imbalances that are within the control of the supply side; walking times, waiting times and in-vehicle travel time (this one may be an exception), as they may differ more significantly not only between different areas and links, but also between same links of opposite directions of travel as total travel time did. This will identify where measures may be more appropriate.

VI.3- WALKING TIME.

Walking time is considered to be the time spent on the way to the bus stop at the origin and the distance from the alighting point to the final destination, as well as in transfer when applicable. It is expected that those living within the Core will spend less time walking than those who live in peripheral areas, as network density may also be higher within the Core than in the peripheries. Walking time may be taken as a measure of accessibility to the system.

The same approach as the one adopted for analysing total travel time is used for analysing variations in walking time and to assess physical accessibility to the system.

Table III presents the variations in walking time according to the nine cell matrix of origin and destination.

TABLE III

WALKING TIME VARIATION (in minutes)

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	9.2	11.9	15.0*
Imm.Periphery	11.8	10.5	11.1*
Int.Periphery	16.4	15.0*	14.4*

* Small sample size

What it is clear from this table is that access to transport facilities is much easier for those living and working in the Core, and for those who live or work outside the Core their walking times tend to increase, maybe as a result of lower network density. No imbalance was observed between the symmetric cells figures, which seems to be consistent, as walking times are not under influence of any external factor only the distance. The exception is the cell O_{32}-O_{23} that. presented a ratio of 1.35, with no plausible reason for such a difference; but this figure is based on small sample sizes.

To give evidence of how the network is more dense within the Core, it may be observed that the ratio between those living in the Intermediate Periphery who work in the Core and those who both live and work there is a figure such as 1.78. The same figure drops to 1.28 if the Immediate Periphery is considered in comparison to the Core.

VI.4- WAITING TIME.

Waiting time is considered as the period spent at the stop from the time the user actually arrives, until he boards the vehicle at the origin plus any eventual waiting time at a transfer. Waiting time is one of the variables used to assess frequency of the services as well as their reliability. Waiting time seemed to be one of the most useful variables to support the argument that services are much more unevenly distributed than would be expected in peripheral areas of Rio de Janeiro.

Services in Rio de Janeiro do not operate according to any fixed schedule so passengers arrival at the bus stops may be assumed to be at random. Usually routes are expected to operate with a minimum number of vehicles, and this varies according to the period of the day. Real headway will be determined by the inspector at the final stop, who authorises drivers departures.

Under the assumption of random passenger arrivals at bus stops, many models were developed and passengers expected waiting time was mainly determined to be a function of services headway and its variation (Welding, 1957; Holroyd and Scraggs, 1966; Osuna and Newell, 1972).

Jollife and Hutchinson (1975) improved these models by classifying passengers into three categories; a proportion q, whose arrival at the stop was coincidental with that of the bus, a proportion (1-q) p who arrived as to minimise expected waiting time and the last category, a proportion (1-q) (1-p) who arrived at random.

Hutchinson has found through observation of passengers and vehicle arrivals at ten bus stops in suburban London that the arrival times of buses and passengers at stops were clearly associated. This was explained as a high rate of passenger arrivals existed at times when the expected wait for a bus was small. His study also demonstrated that a significant passenger arrivals were coincidental with bus arrivals, and thus no waiting time was incurred. Finally, it was reported that the average waiting time for the remaining passengers was still below that for passengers arriving at random, and the effect was particularly evident in the peak periods.

Turnquist (1978) adopted this approach to test his model, but considered only random and non-random passengers. Passengers arrivals were not assumed to minimise expected wait time, but rather were related to an arrival time which results in a fixed probability of missing a bus. This assumption reflected a more risk averse behaviour of people with time constraints, especially commuters.

Findings related to waiting time support the intuitive argument that when services are predictable (low variance), more passengers coordinate their arrivals with that of the buses, resulting in lower average waiting times. When the variance increases more passengers arrive randomly at stops, since there is no obvious benefit in behaving otherwise. Therefore, the assumption of random arrivals is only valid for short headway.

What it was quite interesting in all the models developed to estimate passengers waiting times is that none of them have considered the possibility of waiting time being also affected by loading ratios that could constrain passengers access to the first vehicle, but rather the frequency of the services and headway variation. The existence of an alternative route also plays a decisive role in setting up waiting times.

In the Rio de Janeiro empirical study it was possible to support the argument that waiting time is also a function of crowding and it is not by chance that peripheral commuters who work in the centre face waiting times significantly higher than those who live in central areas and work in peripheral areas. Both use the same routes but in opposite directions which means that no difference on the supply provided occurred, but a concentration in the current demand in one of the directions. Figures for waiting time in the Rio de Janeiro study also support the argument that services in peripheral areas are more likely to have a higher variation in headway due to congestion, which may explain overall increase in waiting time which is reinforced by the lack of an alternative route.

Previous studies of Câmara (1986) on the 394 route came out with findings such as to guarantee a seat on the journey towards the Core in the morning peak period, the user had to form a new queue that would only allow his boarding on the fifth or even sixth vehicle leaving Vila Kennedy, ending up with waiting times of approximately 60 minutes in the morning peak, or approximately the equivalent time as in-vehicle. So the ratio between waiting time and in-vehicle time, may be an useful tool to assess the balance between demand and supply. The higher the ratio, the higher the imbalances.

Table IV presents average waiting time according to the matrix of housing and job-study location.

TABLE IV

WAITING TIME VARIATION (in minutes)

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	6.5	11.9	6.0*
Imm.Periphery	13.9	14.7	20.0*
Int. Periphery	22.1	28.8*	18.7*

* Small sample size.

Waiting time seems to be the most critical component of travel time. If the waiting time for all those who work in the Core and live in both peripheries in comparison to those who live in the Core itself is analysed, ratios of 3.4 and 2.1 are found respectively for Intermediate and Immediate Peripheries. Between the former and the latter one the ratio is 1.6. Hypothesis 1 is then totally supported here.

When symmetric cells are considered, for those living in the Immediate Periphery who work in the Core face waiting times 16% higher than those who travel in the opposite direction. The ratio between both peripheries symmetric cells is 1.44. The most critical observed ratio is between the Core and Intermediate Periphery cells, 3.68, but the size of the small sample of commuters who live at the Core and work at Intermediate Periphery must be considered. Hypothesis 2 is also supported here.

The diagonal ratios are as follows: O_{33}-O_{11}=2.9, O_{33}-O_{22}=1.27 and finally O_{22}-O_{11}=2.26, providing evidence that services are also poorer within peripheral areas and not only from there to the Core. Here it may be said that services are likely to be less reliable, and certainly higher variance in the headway may explain better the higher figures than congestion did in the previous cases among symmetric cells.

The supply of the services does not vary according to the direction of the journey, consequently no significant variations would be expected among symmetric cells. So the only explanation of the higher waiting time towards the Core is due to loading ratios that may be affected by the impossibility of boarding the first bus and higher variation on the headway due to higher congestion towards the Core in the morning peak and towards the Peripheries in the afternoon peak.

Transfer time did not seem to affect very significantly overall waiting time, but peripheral dwellers are the ones whose transfer time shared a higher percentage if compared to the waiting at the origin, due to the fact that more transfers were observed among peripheral householders.

VI.5- IN-VEHICLE TRAVEL TIME.

In-vehicle travel time considers only the time users spend on the way from their origin to their final destination, including travel time in a second or even third mode or different bus route if they made transfers.

Similar to the other components of total travel time, in-vehicle travel time also presents a pattern like the previous ones, where it is observed that trips made within the Core are shorter in comparison to trips made in peripheral areas, and especially from peripheral areas to the Core. Two factors may explain simultaneously the variation in in-vehicle travel time; distance and congestion.

Table V presents the variation observed in in-vehicle travel time according to the origin-destination matrix.

In-vehicle travel time results suggest that distance really plays a decisive role in setting up travel time in the vehicle. The observed ratio between those living in the Intermediate Periphery and Immediate Periphery who work in the Core and those who both live and work there is 2.31 and 1.86 respectively, providing evidence that the former ones face much longer journeys to work than the latter one.

TABLE V

IN-VEHICLE TRAVEL TIME VARIATION (in minutes)

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	29	58	53*
Imm.Periphery	54	41	32*
Int.Periphery	67	41*	44*

* Small sample size

If figure for the diagonal cells are analysed, a ratio of 1.4 is achieved between those who travel within the Immediate Periphery and those who travel within the Core. A similar ratio of 1.5 is observed between those travelling within Intermediate Periphery and the Core.

If symmetric cells are analysed one unexpected result was found. The ratio O_{21}-O_{12}=.93 is for the first time smaller than one. The other two symmetric cells ratios were respectively O_{32}-O_{23}= 1.28 and O_{31}-O_{13}=1.26, both being very alike. Higher figures for trips towards the Core may be explained by congestion. As stated previously in Section IV.2, operating speed may be on average 30% lower towards the Core in the morning peak, and from the Core in the evening peak.

VI.6- WAITING TIME AND IN-VEHICLE TRAVEL TIME RATIO.

The ratio waiting time and in-vehicle time seems to be very useful in assessing imbalances between the supply and demand. The closer to one the ratio gets, the higher the imbalances. Table VI presents the ratio between waiting time and in-vehicle travel time.

TABLE VI

WAITING TIME -IN-VEHICLE TRAVEL TIME RATIO (%)

	WORK-STUDY PLACE		
HOUSING	Core	Imm. Periphery	Int. Periphery
Core	21.6	20.6	11.3*
Imm. Periphery	25.9	36.6	62.5*
Int. Periphery	32.8	70.7*	43.2*

* Small sample sizes

From the results it is clear how the ratios increase towards peripheral areas and also from peripheral areas to the core, providing evidence that imbalances really occur in these areas. Also diagonal figures have increased towards peripheral areas.

VI. 7- NUMBER OF TRANSFERS.

After presenting total travel time and its respective components what was already expected was found, that Core householders spend less time commuting than peripheral ones. Longer distances, congestion and loading ratios seemed to play a decisive role in setting up total and partial travel times, and explaining the differences between central and peripheral areas.

To what extent are these times also influenced by the number of transfers some users are subjected to, and what are the effects that these interchanges may also have on total travel monetary costs?

Table VII presents the incidence of transfers, considering the percentage of the individuals in each cell that make at least one interchange.

TABLE VII

INCIDENCE OF TRANSFERS

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	5%	38%	100%*
Imm.Periphery	35%	26%	17%*
Int. Periphery	40%	54%*	44%*

* Small sample size

The pattern presented in Table VII seems to be correlative to all the other variables presented previously, and transfers are more likely to occur in peripheral areas or between peripheral areas and the Core. While only 5% of the sampled dwellers who lived in the Core transferred , figures rise to 40% among those living in the Intermediate Periphery and working in the Core. A similar increase is observed among the diagonal cells.

The symmetric cells ratios were O_{21}-O_{12}=0.92, which seems quite reasonable. The two others were, O_{31}-O_{13}=0.4 and O_{32}-O_{23}=3.17 and do not allow any further conclusion.

The most important impact of transfer, apart from the discomfort, inconvenience and the likely increase of total travel time due to extra walking and waiting at transfer points, is the increase in travel costs, as there is no fare integration in the Rio de Janeiro public transport system. In the next section variations in monetary costs are presented and also the increase in travel costs due to transfer.

VI.8- ABSOLUTE AND RELATIVE MONETARY TRANSPORT COSTS.

Passengers travel monetary costs are principally a function of the number of transfers, partially a function of the length of the journey and to some extent to the type of the route.

It was shown in Chapter III that there are ten fare categories, and although most of the routes are charged fare category III, the ones that are charged higher values operate mainly in links between the Core and peripheral areas. Although fares are to some extent proportional to the length of the trip, there is no discernible pattern that establishes clear boundaries between distance and fare levels. A shorter route may be travelled and a higher fare may be charged than in a longer route, if that link is a North Radial type one. It was also shown that demand influences fare levels.

As was also mentioned in Chapter III (Section III.V.2), the fare system is a flat one which brings some advantages for those who travel longer distances in a single route to the detriment of those who travel shorter distances. However, the fare charged for longer journeys is proportionally lower, than the one charged for shorter journeys.

But the system still penalizes those who interchange, who may pay another fare. As it was already seen in the last section, the ones who tend to make more interchanges are those who live in peripheral areas and travel to the Core. These users do not think that they pay relatively less for their long distance journeys, in comparison to the shorter routes operating in central areas. Moreover they may also travel in these routes to reach their final destination.

From the fifteen routes surveyed, two out of three that were not charged fare category III were links between the Core and Intermediate Periphery, supporting the argument that the absolute costs for transport are higher for these routes' users.

So peripheral householders travel longer distances to reach the main Core, consequently fares, in absolute terms are higher, even if they do not transfer. If it is considered that the socioeconomic distribution of the population in spatial terms, is inversely proportional to the distance from the Core, relative monetary costs of peripheral population may reach up to 30% of some individuals' income.

Table VIII presents daily costs of transport according to the origin destination matrix. The figures shown in Table VIII also includes those who are travel voucher holders. No significant difference was observed when these individuals were not considered.

TABLE VIII

DAILY MONETARY TRANSPORT COSTS VARIATION** (IN BRAZILIAN CURRENCY- NCZ$. OCTOBER, 1989)

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	2.41	3.24	5.80*
Imm.Periphery	3.55	3.53	4.80*
Int.Periphery	4.12	4.70*	3.64*

* Small sample

* * Figures are relative to October 1989

As it was expected travel costs increase proportionally to the distance travelled and number of transfers. The ratio between those who live in the Intermediate and Immediate Peripheries and work in the Core and those who both live and work there is respectively, 1.70 and 1.47. The ratio between those living in both peripheries was 1.16. A crucial contradiction emerges from these ratios. Income distribution concentrates those better off in the Core and those with lower earnings in peripheral areas. So it can be concluded that the further away a person lives, the lower his earnings, the more he travels in terms of distance and time, at higher costs in absolute terms and even higher in relative terms.

No significant difference is observed among those living in the Immediate Periphery, according to their destination of work or study, except if their destination is Intermediate Periphery and the same applies to the symmetric cells O_{21}-O_{12}.

It is believed that monetary travel costs may represent a factor that constrains the degree of movement of people. If travel costs account for a high percentage of someone's income, their mobility will be affected and maybe they will not travel for any purpose other than to work.

It is interesting to mention that a higher percentage of travel voucher holders was observed among those living in peripheral areas, (6.4%, 14,3% and 26.4% lived respectively at the Core, Immediate Periphery and Intermediate Periphery). For the whole sampled population, travel vouchers accounted for 9.9%, including only those with a paid job within the formal market. If on one hand this reduces the impact of transport costs for those individuals with lower budgets, on the other it only insures them the use of public transport for trips with working purposes.

Table IX presents the relative costs of transport, given that peripheral householders spend more in transport in absolute terms and earn less. Consequently, a different pattern may be expected. In this table only those who have earnings were considered, and students or those with no earnings were then deleted. Relative costs were calculated multiplying daily costs in transport by the weekly frequency and finally by four (considering four weeks per month) and then dividing it by monthly income.

TABLE IX

RELATIVE MONETARY TRANSPORT COSTS VARIATION

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	7.12%	7.80%	5.20%*
Imm.Periphery	7.88%	7.17%	24.50%*
Int.Periphery	11.40%	12.20%*	4.8%*

* Small sample sizes (respectively, 2,4,13 and 2- as only those who work were included).

The most interesting finding from Table IX is that none of the five cells with significant sample sizes had fallen within the acceptable level of monthly expenses in transport determined by the Government, that is not to exceed 6% of any individuals' salary. Moreover, very similar figures of around 7% in four of the five cells are observed, the only exception being the cell that links the Intermediate Periphery to the Core, providing evidence that for this group transport may represent a severe burden on their monthly income (11.4%).

Also noted is that those living in peripheral areas face two constraints; the first one a time constraint as a result of living further and spending more time commuting, they are more likely to be more restricted and make fewer trips than those living in Central areas; second, a financial constraint, as their income is mostly lower, they will also be restricted on the amount of their travelling. So when their relative costs are higher, it must be considered that these costs may be even relatively higher, if they travel less (number of journeys) at a higher cost in absolute terms.

In order to check the direct impact transfer may have on travel costs, figures for daily costs in transport for the whole sampled population are presented, considering those who interchanged and those who did not. Housing or job-study location is not relevant here. Figures respectively for those who interchanged and those who did not were, 4.77 and 2.74 Cruzados. This represents an increase of approximately 75% on the daily transport costs (absolute figures) for those who did not have a direct service for their daily commuting. These figures refer to October 1989, when the survey was carried out.

Now relative costs figures are presented. These represent the percentage of an individual income that is committed to transport. Here, only those who had an income were considered. It is expected that those who interchange may spend more in relative terms than those who do not. The explanation lays in two facts; first, those who interchange pay more in absolute terms and second they are less well off than those who do not interchange.

In fact, those who interchanged had committed approximately 12.41% of their earnings to transport, while those who did not transfer only 7.57%. This figure is still higher than the ideal 6% established by the Government as the maximum a worker should spend on transport, relative to his earnings. In general, an interchange accounted for a 64% increase in transport costs (relative figures), if housing and work location is not considered.

When the spatial variable is considered an interesting picture may be drawn. Table X presents the daily costs with transport taking into account non-interchange users and interchange users (ranging from one to three interchanges). On the first column figures of those who did not interchange (NI) are found , while the second one refers to those who did transfer (I). Figures for the cells with small sample sizes were not considered.

TABLE X

COMPARATIVE MONETARY DAILY TRANSPORT COSTS DUE TO TRANSFER (in Cruzados- October 1989)

	WORK-STUDY PLACE					
HOUSING	Core		Imm.Periphery		Int.Periphery	
	NI	I	NI	I	NI	I
Core	2.43	4.21	2.84	4.00	-	-
Imm.Per.	3.13	3.95	3.02	3.79	-	-
Int.Per.	3.60	5.05	-	-	-	-

From the figures presented in Table X, it is observed that in fact, transfer increases travel costs significantly. The increase ratios ranged from 26% and 27% for those living and working in Immediate Periphery and also for those from Intermediate Periphery working in the Core respectively, to 73% for those who lived and worked within the Core.

If relative costs in transport is analysed as a resultant of transfer the figures presented in Table XI may occur, where the only cell that transfer did not incur in an increase in relative costs in transport was the one of those who lived and worked in the Core. The explanation may be that income levels of those who interchanged compensated the ratio. In the all other cells relative increases were observed, especially in the cell of those who lived in Intermediate Periphery and worked in the Core; 15.67% and 8.6% respectively for those who made interchanges and those who did not, representing a relative increase of 82% in their relative monthly costs in transport. The cells with small sample sizes were not considered here.

TABLE XI

COMPARATIVE RELATIVE MONETARY TRANSPORT COSTS DUE TO TRANSFER (in Cruzados- October, 1989)

HOUSING	Core		Imm.Periphery		Int.Periphery	
	NI	I	NI	I	NI	I
Core	7.2 %	6.2%	6.2%	10.1%	-	-
Imm.Per.	6.4%	9.5%	6.0%	9.8%	-	-
Int. Per.	8.6%	15.6%	-	-	-	-

It may be concluded that those worse off are the ones who live in Intermediate Periphery and work in the Core. They are the ones more likely to travel longer distances, to spend more time commuting at higher costs, to make more interchanges, and finally at higher relative costs of transport.

Some measures have been already taken as an attempt to alleviate this problem such as the travel voucher scheme (Chapter III). One of the greatest criticisms of this policy is that only those employed in the formal sector are eligible for the voucher; it does not include civil servants. Nevertheless most of the working class in Brazil are either self employed, work in the informal market or are civil servants. In addition to the voucher scheme, recent policies have allowed school children dressing uniforms and elderly (over 65 years old) to travel for free.

VI.9- COMFORT CONDITIONS.

One way of assessing comfort conditions according to the matrix is to investigate how passengers usually travel; either seated or standing. The same approach is adopted here, and Table XII shows the percentage of passengers that declared to travel always seated.

TABLE XII

COMFORT VARIATION- always seated

	WORK-STUDY PLACE		
HOUSING	Core	Imm.Periphery	Int.Periphery
Core	79%	90%	100%*
Imm.Periphery	67%	77%	83%*
Int.Periphery	67%	61%*	55%*

* Small sample size.

It is important to observe that comfort conditions are much better for those living in the Core, although the reverse may have been expected. This particular distribution is due to a higher turnover in the routes operating in central areas, increasing the availability of seats, while in routes from peripheral areas to the core a low turnover is observed, and most of the passengers travel the whole extension of the route.

If symmetric cells are considered it is noticed that services towards the Core are less comfortable than in the opposite direction, as a result of the concentration of demand. The ratio O_{21}-O_{12}=0.74 for instance, provides evidence that while 33% travel standing from the Immediate Periphery towards the Core, only 10% do so in the opposite direction.

As it would be expected, comfort conditions at the diagonal cells also decreases towards peripheral areas. If figures are considered in a aggregate level, according to housing location, 81%, 71% and 65%, respectively living in the Core, Immediate and Intermediate Peripheries, declared to travel only seated.

If it is taken into account that those living in peripheral areas face longer in-vehicle travel time under lower comfort conditions, and that those living in central areas travel shorter distances under better conditions of comfort, it may be may concluded that in relative terms, comfort conditions is really an important issue to be tackled.

If longer walking distances and waiting time for those living in peripheral areas is considered in a comparative basis with those living in central areas, it becomes clear how inequitable services are for those better off who live in central areas and those less well off who live in peripheral areas.

VI.10- CONCLUSION.

From the figures presented within this Chapter it was possible to identify not only the most critical areas in terms of the quality of services provided, but also the social groups to whom services are of a poorer quality and a lower reliability. Intermediate Periphery area, basically inhabited by lower income groups, most of whom work in the Core, accounts for the most critical link. This is the Intermediate Periphery-Core link.

The great dependence of the labour force on the Core on the one hand and on the other, the great dependence of commuters on the bus system, seems to affect the overall performance of the transport system in Rio de Janeiro. This land use pattern concentrates demand in a way that approximately 40% of the trips generated daily in Rio de Janeiro occur in the morning peak from 07.00 am to 09.00 am and in the afternoon from 17.00 pm to 19.00 pm. And the bus system caters for 80% of the total demand.

Consequently, Intermediate Periphery householders are the ones subjected to longer distances from home to work, are penalised with a greater number of transfers, have a higher variability in headway, higher loading ratios, less comfort, higher fares, and as a result of a non integration fare scheme, also face higher expenses in travel.

Given this overall picture of where the imbalances are more apparent, who are the most affected and finally some explanation why these imbalances occur, it may be possible to set some possible measures to minimise these imbalances.

An evaluation of some of the classical attributes analysed in the previous sections is presented in Diagram II, in order to give a general view of the Rio de Janeiro bus system according to the three areas considered, for Housing and Job or Study locations, identifying the most crucial problems and where they are occurring, as a guideline for a strategy for any further proposals. They were categorised according to expected values, worse than the expected values, and lastly better than the expected ones.

As seen in the diagram, the most critical area is definitively Intermediate Periphery, for which most of the considered attributes have achieved higher figures than expected, the only exception being in-vehicle travel time. Due to the longer distances these figures were expected to be higher anyway. Comfort conditions were lower than expected. In other words, it was expected that more passengers would travel seated from the peripheral areas to the Core. A high percentage of the sampled population living in the Intermediate Periphery make transfers on their daily commuting, increasing their costs significantly.

On the other extreme there is the Core householders, for which most of the figures were either expected ones, or even lower than expected values. The comfort condition was surprisingly greater than expected as most of the passengers travelled seated along areas with very high demand. The only figure greater than expected relates to the destination Intermediate Periphery.

For Immediate Periphery area some figures were greater, others were lower and even some figures were expected. This provides evidence that this area is somehow at an advantage if compared to the intermediate periphery. This is certainly because of its proximity to the Core.

So the Core is the best serviced area among the three areas followed by Immediate Periphery, which is better serviced than Intermediate Periphery. So the strategy for tackling the problems of transport in Rio de Janeiro, may consider the Intermediate Periphery as the priority area, and then Immediate Periphery and lastly the Core.

From all the attributes considered, some of them are more directly concerned with the provision of the services itself, such as waiting time while others, e.g. in-vehicle travel time, are under influence of some external factors, such as congestion. The ones that are more directly concerned with the operation itself, are the ones likely to be tackled more easily.

It may be concluded that waiting time is the most critical attribute, being really uneven among the three areas, and that is directly concerned with the operation of the system , and that most passengers are directly affected by it. The disequilibrium between supply and demand seems to be considerable at peripheral areas, and waiting time was revealed to be a function not only of the frequency of the services, but also a function of loading ratios, that may constrain the access to the first vehicles. In some areas in peripheries, users board on the fifth or sixth vehicle. The possible alternative routes are discarded because they charge higher fares.

The monetary costs of travel are also an attribute that has presented a considerable imbalance between the three areas. On average most of the figures were greater than expected, the only exception being two cells for living in the Core and one cell for those living in Immediate Periphery, otherwise travel costs were rated greater than expected. These figures are results of both travel costs; higher for longer journeys, and number of transfers, as no fare integration scheme exists in Rio de Janeiro bus system.

In-vehicle travel time is mostly under expected values, and at this stage it is almost impossible to unravel to what extent travel times in vehicle is due to the distance covered or due to congestion and traffic flows. As described in this Chapter, it may be concluded that in more central areas operating speeds are lower, due to congestion and journeys take relatively longer; but in general, in-vehicle travel time seems to be clearly related to the route length.

The magnitude of the problem may be summarised in travel time and travel costs. These two issues may guide the alternative measures that will be considered to minimise the imbalances and inequalities in the services, between the Core and Intermediate Periphery or between those wealthier and poor segments.

Next Chapter will consider some alternative proposals to tackle the imbalances detected in the Rio de Janeiro bus services.

DIAGRAM II-
EVALUATION OF SOME CLASSICAL ATTRIBUTES ACCORDING TO HOUSING AND JOB LOCATION

Key words;
E, as expected.
G, greater or worse than expected.
L, lower or better than expected.

1- Core.
2- Immediate Periphery.
3- Intermediate Periphery.

Area	Live →	Core			Imm.Per.			Int.Per.		
Attributes	Work →	1	2	3	1	2	3	1	2	3
Total Travel Time		E	E	E	G	G	G	G	G	G
Walking Time		E	E	G	G	E	E	G	G	G
Waiting Time		L	E	L	G	G	G	G	G	G
In-Vehicle Time		L	E	L	E	E	L	E	E	E
Transfers		E	E	L	E	G	L	G	G	G
Travel Costs		E	E	G	E	G	G	G	G	G
Comfort		L	L	L	E	E	E	G	G	G

CHAPTER VII- SELECTED OPTIONS

VII.1- SELECTION CRITERIA.

The findings presented in this work allow some conclusions to be drawn regarding the provision of the services of public transport in Rio de Janeiro; significant differences in the quality of the services were observed given the socioeconomic inequalities and the respective spatial distribution of the population. This chapter suggests some alternatives that are intended to improve the public system aiming at spreading services more evenly throughout the city of Rio de Janeiro.

However it must be taken into account that any of the measures suggested here may be not totally successful given the fast expansion of car ownership levels and the consequently expected use of these cars, as shown in Chapter III (104 vehicles per 1000 people in 1980 to 190 vehicles in 1989 per 1000 people).

As stated previously (also in Chapter III) the Metropolitan Region of Rio de Janeiro is mainly served by the bus (80.1%), the railway (11.8%) and the underground (5.5%). The boat caters for only 2.6% of the total demand of public transport. Each of these modes cater for specific demands in socioeconomic terms, present different operating characteristics and consequently face different deficiencies.

On the one hand the bus transit, among all modes of transportation currently in operation in Rio de Janeiro, has most flexibility, requires least investment and least infrastructure costs. It also allows easily re-routing and extension of the existing services at relatively low cost and within a very short period of time.

The system is also flexible if the large range of services offered is considered, from local ones with frequent stops and maybe a lower capacity vehicle, to an express service with higher capacity vehicles and limited stops. Appendices VIII, IX and X present respectively a summary of the investment required for different transit systems and fixed equipment costs, vehicle costs and finally total system costs.

On the other hand, light rail system, rapid rail transit and suburban rail lack flexibility and also require a much higher level of investment for implementation and infrastructure costs. In addition, re-routing and any extension of services in operation may be highly restricted and discouraged.

Given the modal spilt in Rio de Janeiro, where the bus system still caters for approximately 80% of the total public transport demand, the degree of inequalities observed in those services provided between wealthier and poorer areas, and finally the lower cost of improvements that can enhance a bus system performance; it may be considered that the bus among all other modes of transportation should be given priority in a shorter term scenario.

However, the railway and underground systems should not be neglected because the bus system may not cope with this high share of demand for a long time. In addition the railway demand is mainly from the lower income groups. So the social benefits of any improvements within that system would be significant for those lower income groups. The bus transit capacity may also be constrained depending on the volume and direction of demand and the different rights of way in which the system operates (significant differences may occur when the system operates in mixed traffic conditions or in segregated busways).

After identifying the Intermediate Periphery population as the target group or the target area for immediate action, as they were the ones most affected by a poorer service, the sort of measures that should be taken to minimize the degree of inequalities may be defined. In previous chapters the most critical problems faced by that group could be identified, who living in the Intermediate and Immediate Peripheries still remained working in the Core.

In general, travel costs and travel time seemed to be the most crucial problems that affected lower income groups more effectively. Given some characteristics of the land use and of the transport system, it can be seen that some problems are really difficult to tackle with actions taken only within the transport field. As a result of living further away and having to overcome longer distances to work, in-vehicle travel time will always be longer for them than it is for those living closer to the Core. But some disparities as a result of imbalances in services provision were detected among the three areas considered in this study, especially walking and waiting times. These attributes of the services are the ones which are possible to be reduced and that require some kind of action within the transport field. It seems that the nature of the problem lies at the imbalance between supply and demand, and more specifically on the spatial and temporal concentration of this demand.

It is important to outline some of the proposals of the new Master Plan for Rio de Janeiro concerning actions in the transport sector. According to the discussions related to this plan, some guidelines were drawn such as railway upgrading, aiming at recovering lost patronage, targeting a daily demand of 1.2 million passengers. The operation of the Underground Line 2, between Triagem and Pavuna (from Triagem to Irajá services have been cancelled for a long time - see Rio de Janeiro Underground Network map, Chapter III), serving mainly Immediate and Intermediate householders and even the implementation of light rail systems was encouraged, especially the tramway. In the bus transit sector proposals were mainly concerned with network rationalisation and changes in the fare structure. Simultaneously to this plan a new road scheme is being proposed named "Linha Vermelha" to be built parallel to Brazil Avenue, aiming at alleviating the heavy traffic flows in the mentioned corridor.

If a selection criteria is established considering the three transit systems already in operation in Rio de Janeiro, with no doubt the bus should be given priority; Firstly because it is representative (80% of the total demand for public transport) and secondly because of the system flexibility, followed by the two other modes currently available in Rio de Janeiro, the railway and the underground.

The next section presents the selected options within each specific mode of transportation according to their social effectiveness. In other words, they were selected according to a social appraisal, being the social objectives of the selected options addressed as the guidelines for any future intervention. At first it is presented measures within the railway and the underground systems and then within the bus transit.

VII.2.2. WITHIN THE RAILWAY AND UNDERGROUND SYSTEMS.

In previous chapters it was shown that both the railway and the underground systems faced serious problems concerning their operation and that their effective patronage was far behind the potential one. While the railway capacity has been constrained by the lack of improvements in the operating system, the underground capacity has been constrained by the non completion of the basic network initially proposed. Consequently these two modes should not be neglected because the bus may not be able to keep catering for 80% of the public transport demand continuously.

On the one hand the railway also faces problems related to lack of investment in the last years, which really deteriorated the system substantially and on the other, the underground system has been facing serious disruptions in its construction process, leading to a poor performance and productivity of the system currently in operation. To worsen the situation the lack of integration of these two modes and the bus contributes for the loss of patronage to the bus of these higher capacity modes.

So, a first attempt to increase patronage in both systems would be a comprehensive integrated system allowing users to travel by all modes of transport available paying only one fare. Then, revenue sharing should consider the proportioned operating costs of each of these modes separately.

Parallel to this integration of the transport system, improvements are necessary to the railway system in order to improve the system performance and increase its reliability, consequently increasing patronage, especially in peripheral areas, where most of its demand lies.

The completion of the underground network seems to be fundamental in justifying all investment already made for its partial construction. The bus competition may no longer be stimulated along corridors both modes are currently operating. As shown previously this competition may affect the bus performance at the same time that it affects the usage of the higher capacity mode.

However the costs involved in improvements in both systems may vary considerably. According to the Work Bank (op. cit.), upgrading a railway system already in operation, may account for substantial improvements in the system and involve investment of low cost as most of the track is already built, representing only a small fraction of the cost of a new metro system that may cost up to US$ 120 million per kilometre, including structure, track signalling, power stations and depot. According to Chapter III, the expansion plan for the underground in Rio de Janeiro, still requires 18.5 kilometres to be built, which may require investment of approximately US$1.85 billion (the cost per kilometre in Rio is estimated to be US$100 million- Allport , R. J., et. al. op. cit.).

Although high investments are required for the underground expansion it is highly recommended that funds should be allocated for its completion, otherwise all the investment already involved will never be recovered, and worse than that the social benefits expected with this system implementation will not be achieved.

VII.3- WITHIN THE BUS TRANSIT.

VII.3.1- Introduction.

The main characteristic of the bus transit in Rio de Janeiro is the nature of its operation. Services are run privately by 33 operators, accounting for most of the fleet and routes in operation. The public operator participation has been declining substantially lately. The system operates under severe competition between operators and other modes of transit, such as the underground and the railway, especially in areas of higher and concentrated demand. Most of the deficiencies observed within the bus mode may be to some extent related to its private and competitive operation structure and the lack of integration among operators and between them and the other modes of transportation. In order to maximize profits services are operating with no rationality.

On the one hand in peripheral areas, where demand is lower, another market logic seems to apply and a kind of operators market monopoly or the monopoly of different catchment areas by certain operators can be observed (Oriental operator in the West Zone and Redentor in the area of Jacarepaguá are classical examples), and this subjects users to lower standards of service as there is no other operator competing in the area. In those areas, operators take advantage of the lack of competitors and services usually operate with higher headway. Consequently utilisation is maximised and this in turn overcrowds the vehicles, constraining the access of users, leading to longer waiting times.

On the other hand and contradictorily, the utilisation of services in central areas may be substantially affected by the high competition there, and lack of it in peripheral areas, which in turn leads to imbalances between demand and supply in some routes or areas. In addition, operating costs have been subject to frequent increases in fuel, spares and labour costs, caused by the economic crisis that the country faces. Consequently fares have been rising constantly and this may also affect ridership.

As stated previously the bus is the most flexible transit system and its performance may vary substantially according to the vehicles in operation, road characteristics and road capacities. Two extremes situations may be established; one covering operation in mixed traffic conditions and the other in totally segregated bus ways.

The most critical problems faced by public transport users in Rio de Janeiro were related to travel time and travel costs. Most of the policies or goals must aim at time and costs reductions, as well as overall improvements in the quality of the services, especially in the link from the periphery to the core. In fact, according to the World Bank (1986), the primary benefit for transit users in developing countries is related to savings in journey times and the magnitude of the benefits will depend mainly on the number of passengers involved and the value placed on the time saved by each passenger.

Some strategies for action may be foreseen for the Rio de Janeiro bus industry within a political and managerial contexts that could improve its performance and productivity. Actions that would require low investment include;

1- Changes in the regulation of the services currently in operation (aiming at stimulating a more integrated system).

2- Rationalisation of the network (this measure would certainly lead to higher operating speeds and consequently to savings in in-vehicle time and a likely lower variability in headway; In addition, shorter waiting times may occur, especially for those living in peripheral areas).

3- A new fare structure, including a fare integration scheme (this measure would alleviate the burden of transportation costs for those living in suburban areas and that are likely to make more interchanges).

4- Recalculation of roads capacity aiming at priority schemes such as reserved bus lanes.

5- Progressive replacement of vehicles currently in operation by ones of higher capacity and greater comfort and the introduction of vehicles of lower capacity such as the minibus to operate in lower density areas, aiming at adjusting the current system capacity to the effective demand as much as possible.

All these actions may take place at two different spheres; at the political and planning level, via regulations and policies where strategies are defined and regulated, and at the operational and managerial levels, where the implementation and changes within the system actually take place.

On the supply side, given the private operation of the system it is expected that the maximisation of profits would be one of the goals of the operators. On the demand side it is expected that minimum travel costs and higher accessibility would be some of the passengers goals. One of the measures that might satisfy both, operators and passengers goals would be to minimise operating costs. The only way this goal may be achieved is by maximising the utilisation of the services. It must be ensured that once operating costs are minimised that also the fare levels are lowered, otherwise operators would maximise their profits even more, and users would not benefit from any of the measures eventually taken.

To minimise operating costs, the system overall efficiency and productivity must be improved. Some measures for a short term and low budget scenario and quick response from the demand side could be taken such as network rationalisation, fares restructure, integrated fare schemes. These are presented in detail in the following subsections.

VII.2.2- Routes Rationalisation.

The first measure aiming at improving the bus system in Rio de Janeiro should be a better allocation of the current fleet in operation by rationalising the distribution of the services. It is believed that services could be improved significantly just by improving allocation of the present fleet, consequently almost no investment would be necessary.

This measure is mainly concerned with the restructuring of the whole routing network in Rio de Janeiro bus industry, setting up a network hierarchy avoiding the current overlap of several routes from different operators in central areas. The main effects of this route overlapping are congestion, lower operating speeds, higher in-vehicle travel time, low services utilisation and hence higher operating costs and higher costs per passenger, consequently higher fare levels. Both operators and users seem to be affected by the lack of coordination within the network in operation.

This overlapping is more evident during inter peak periods when roads remain congested by vehicles not fully utilised, especially within the Core. This may suggest that vehicle size may play an important role in setting up the level of services to be provided. A minibus in this case could be an alternative response, as the vehicle is especially designed to meet lower demand areas, or lower demand periods.

The goals of route rationalisation are to improve the systems overall efficiency by maximising services utilisation, decreasing congestion, hence increasing operating speed, encouraging the coordination of the whole network in a pool of routes and operators. By maximising service utilisation, operating costs could be minimised which could lead to lower fare levels. If fare levels are lowered, an increase in demand may be expected and an even higher utilisation of the services and revenues could be achieved. Although increase in ridership is not necessarily a goal of this measure, it could represent a social benefit as more people would be travelling by public transport as the mobility of the population in Rio de Janeiro seemed to be very low; only 1.11 trips per day per person (Chapter II).

However, this measure cannot be taken separately but only in conjunction with other measures from both the managerial and the operational points of view. These would include fares integration and concession schemes, priority schemes such as bus lanes and other external measures such as parking restrictions in central areas. Also a network hierarchy would be useful to adjust supply to demand and in this case vehicles with different capacities might play a decisive role in it.

Immediate measures could be taken concerning the routes currently in operation and a feasible way to turn this option into practice would be to abolish the diametrical routes operating via the Core, maintaining only the north and south radial route types, both converging to and from the Core, where users who are not travelling to the Core would then transfer, assuring that no extra cost would incur. Integration terminals should allow quick and efficient transfers.

It was observed that the diametrical routes surveyed served basically two different demands; the Core was acting in both directions, either as a the main destination or as the origin.

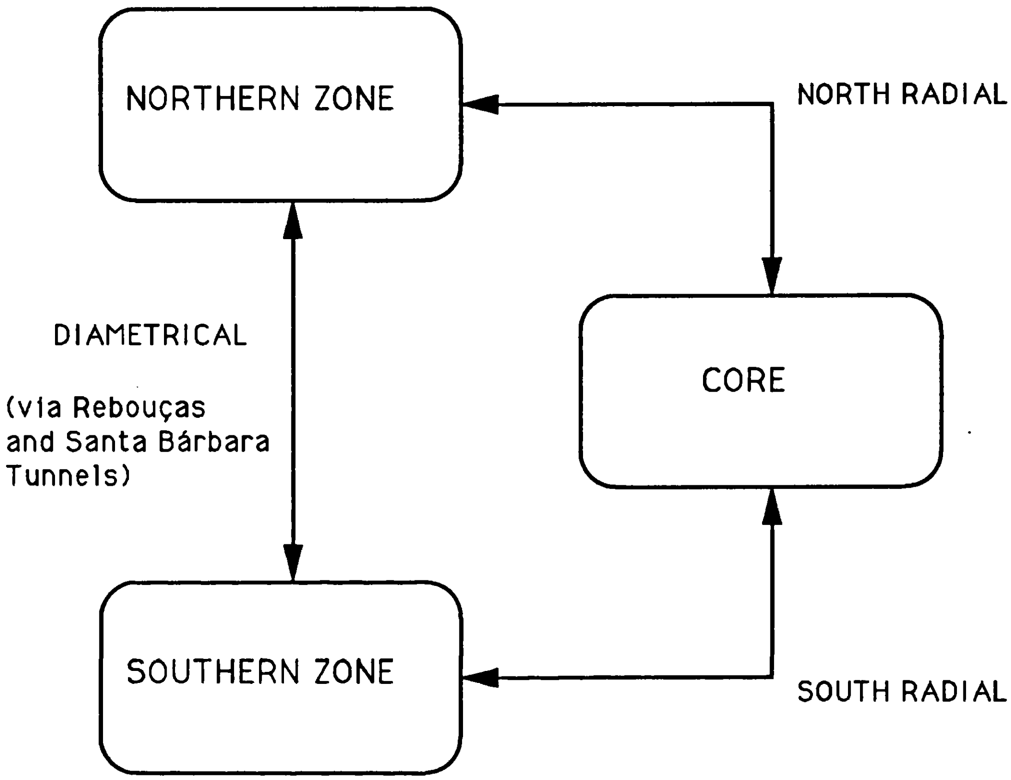
Direct services between the Northern and Southern zones, via both tunnels Santa Bárbara and Rebouças should be created to offset the routes suggested to be abolished. Both of these corridors, constructed in the sixties represented very high investment at the time, but were mainly addressed to the use of private vehicles, as car ownership levels were increasing at faster pace at that time. Currently only few routes make use of these two shorter northern-southern zone corridors. These routes reallocation would alleviate congestion in the main corridors leading to and from the Core. This could certainly increase operating speeds for those who are travelling to that area or within it. The rerouting scheme is shown in Diagram III, remaining the previous North and South Radial route types, while the diametrical routes are suggested to operate direct links, mainly by the corridors Rebouças and Santa Bárbara tunnels, instead of the current services operating via the Core.

It is also important that new links should operate, especially direct services from the far suburban areas to the southern zone, but not only by the main access road Brazil Avenue, but via Madureira and Jacarepaguá areas. These two areas have been emerging as potential labour market areas. However the difficult access or the non existence of direct services may increase overall travel time significantly, reinforcing the core as the most attractive area in terms of job opportunities. So it is important that new links are created to ease the access from both extreme zones to that intermediate area.

The advantage of the service rationalisation is that no investment in infrastructure is necessary, it only requires a different allocation of the fleet already in operation. This option is also flexible and would permit that the measure could be tested for a short period and its performance assessed and then if results are satisfactory, the option could be adopted on a definitive basis.

DIAGRAM III

REROUTING PROPOSAL SCHEME



VIII.2.3- Fleet Renewal.

A bus system's efficiency depends upon many characteristics of its operation and management. The quality of services in Rio de Janeiro seemed to be severely affected by the low standard of the vehicles currently in operation. So it is suggested that a progressive fleet renewal should take place, and in this respect two different vehicle types should be considered to replace the ones presently in operation; higher capacity vehicles for higher capacity corridors, and minibuses should be introduced in services of lower demand or even during inter peak periods.

Minibuses are small vehicles, more manoeuvrable than large buses and consequently they carry less passengers. They also attain higher average speeds primarily due to their smaller capacity, their reduced dwell time and their greater manoeuvrability. Minibuses are certainly more suitable for serving areas with lower density. Also this lower capacity vehicles would suite for periods of lower demand, when a conventional size vehicle would not be fully used. Minibuses should not be seen as competing with vehicles of higher capacity, but rather as a complementary service to higher demand corridors, by acting as feeder services (Banister and Mackett, 1990).

Minibus initial capital costs are quite similar to those of full sized vehicles, that is approximately £1,000 per seated passenger. However their life span seem to be shorter; four to six years against twelve to fifteen of conventional vehicles. This in turn leads to a greater annual depreciation per seated passenger (White and Turner, 1987).

Some characteristics of the minibus, mainly concerned with the size of the vehicle, may influence demand significantly such as higher frequency of the services, faster operating speed, more flexibility and higher penetration into areas the access is difficult. Among many factors influencing demand it may be observed that the most important one contributing to an increase in ridership relates to the increase in the frequency of the services.

It has been estimated that the greater manoeuvrability and reduced stop time could reduce the end-to-end journey time by up to 20% (Banister and Mackett, op. cit.). However this reduction in travel time due to higher operating speed, may be offset by road congestion, if the same number of seats offered by conventional vehicles per hour is provided by this new service (Oldfield and Bly, 1988).

However, there is no general rule for ridership increase. The extent of frequency increase, new routes, improved access and higher penetration, and changes in hours of operation varies considerably (White and Turner, op. cit.).

What is clear is that more minibuses are required to provide the same carrying capacity of big buses (Banister and Mackett, op. cit.), consequently it is argued that a higher frequency service will operate. Empirical evidence has shown that minibuses do operate at higher frequency, varying from three times the conventional vehicle frequency, and sometimes as high as six times.

For the user, a higher frequency service may represent shorter waiting times. But under some circumstances this expected decrease in waiting time may not necessarily occur. According to Hauer (1971) and Oldfield and Bly (1988), a small size bus is more likely to arrive full than a larger vehicle, and so waiting time may be increased, as access to the vehicles may be constrained.

Little or no empirical evidence seem to have shown that the introduction of minibuses have influenced passengers waiting time. Just as it can be argued that excessive waiting times are a manifestation of a mismatch of demand and supply, it can also be argued that another manifestation is overcrowding, which may constrain passengers access to the vehicle, leaving them at the stops, increasing their waiting time (Banister and Mackett, op. cit.).

In this way it seems that this type of vehicle could be appropriate for some areas in Rio de Janeiro with difficult access and lower demand. Also minibuses could play a decisive role in reinforcing the services rationalisation suggested previously.

Minibuses could operate as feeder services for the proper bus system in areas with lower densities, or exclusively residential areas for instance, where services with conventional vehicles are under utilised. Some areas are identified as the ones where the new services could be implemented such as in the boroughs of Cosme Velho, Urca, Leme, all of them in the Southern Zone, or Rio Comprido and Usina in the Northern Zone, or further boroughs in Ilha do Governador and especially in Intermediate Periphery areas, where services are reduced in inter peak periods, as a result of low demand. Here the minibus could operate efficiently as a feeder service for higher capacity transits, such as the conventional bus, the underground and the railway, mainly in peripheral areas.

Concerning the operation of higher capacity vehicles, Municipal Decree 7887 dated from 16-06-1988 established that from the first of January 1990, all the vehicles that have their life span expired should be replaced by vehicles of higher capacity and greater comfort (95 passengers, including standing ones), called "Padron", manufactured by Mercedes.This vehicle is more suitable for carrying passengers with special chassis and air mixed suspension, instead of the vehicles in operation at present that use a lorry chassis and spring suspension. If the referred Decree is adopted the whole fleet in Rio de Janeiro would be replaced by more comfortable vehicles with higher capacity and longer life span by January 1997. However the new Mayor ignored the Decree, and was not interested in the replacement of the old vehicles by these new ones, while the Municipal Transport Secretary has admitted to not being informed about the Decree. On the other hand the operators were the first ones to refute the Decree, arguing that the proposed vehicles cost was almost the double of the vehicles in operation, despite a ten year life span against seven of the vehicles currently in operation.

However, the President of the Urban Transport Municipal Superintendency subordinated to the Municipal Secretary has argued that the implementation of these new vehicles would imply an increase in the fares currently charged, as these vehicles are more expensive than the ones in operation. It could be argued that the higher capacity of the proposed vehicles may enhance the system productivity especially if, in addition, supplementary measures such as rights of way are also implemented, which would lead to savings in operating costs so fare levels could even be lowered. What seems to be occurring in Rio de Janeiro, as a result of the private operation, is that the high revenues margin of the operators must be guaranteed, in spite of the quality of the services being offered. This approach must be changed.

The findings of this research allows conclusion regarding the inadequacy of the vehicles in operation, that the passengers are offered very poor comfort conditions. So it seems that the replacement of those vehicles by those of higher technology would benefit them substantially and it is strongly recommended. The higher costs of the proposed vehicles could be certainly offset by a higher utilisation and productivity, and in this respect measures such as priority schemes could be complementary ones.

It seems that merely putting more buses in service will not necessarily improve the quality of the services. In a congested area such as Rio de Janeiro, measures concerning road capacities may also be considered. In this respect it seems appropriate that further studies identify the more congested roads in order to allow a proposition of a comprehensive priority schemes for the buses.

VII.2.4- Priority Schemes.

Bus priority schemes may improve not only the system overall performance but may also enhance the system capacity significantly as a result of the increase in operating speeds. In addition, the cost for the construction is relatively low if compared to improvements in other transit systems. According to the World Bank report (op. cit.), the costs of construction of exclusive busways in combination with graded intersections may vary from US$2 to US$7 million per kilometre (figures are relative to 1985 prices).

Reserved bus lanes may enhance operating speeds up to 18 Km-h, and passengers volume may vary from 15,000 to 20,000 passengers per hour per lane, depending on the vehicles capacities. When in mixed traffic conditions average operating speeds may be as low as 12 Km-h and the system may handle from 10,000 to 15,000 passenger per hour, per lane. So a 50% increase in operating speed and passengers capacity may be achieved, giving evidence that the benefits are highly significant (World Bank, op. cit.).

In Rio de Janeiro, three separate bus priority schemes have been already implemented; two in the Core area, in the Central Business District, at Rio Branco Avenue, and the other one in the Southern Zone, at Nossa Senhora de Copacabana Avenue, both one way roads. Nossa Senhora de Copacabana and the binary Barata Ribeiro Street cater for 4.4% of the total bus volume in Rio de Janeiro, being considered the volume in 24 main corridors established in the Basic Urban Plan for Rio de Janeiro, namely PUB RIO, in 1977 (Prefeitura Minicipal da Cidade do Rio de Janeiro, PUB RIO, 1977).

The third experience was in the main access road in the city, that is Brazil Avenue, which is a dual carriageway road with a total of six lanes in each direction and a daily volume of 240,000 vehicles in its busiest section from which private cars account for 62%, buses for 11,5%, freight vehicles for 17% and finally taxis for 9.5% of the total volume. However the bus carries approximately 90% of the total passengers who travel in Brazil Avenue (Machado, D. 1988). This road is used by most of the routes between peripheral areas and the Core. According to PUB RIO (op. cit.), this corridor catered for approximately 16% of the total bus volume in the 24 corridors considered in the specific plan.

One of the routes surveyed (394) used this corridor and operated in both; the bus lane scheme on the central track (volume reaches figures of 600 vehicles per hour in both directions) as well as in mixed traffic conditions, on the lateral lanes (here bus volume reaches figures of 400 vehicles per hour in both directions) (Machado, D. op. cit.). However, no significant difference was observed in running time during the morning peak period in either of the two alternatives, giving evidence that only one bus lane was not sufficient to enhance operating speeds, especially in peak periods, due to the high volume of traffic.

The Transport Engineering Programme (COPPE- Federal University of Rio de Janeiro) carried out a traffic volume counting before and after the implementation of the bus lane at Nossa Senhora de Copacabana Avenue, in 1985. This corridor presented in the morning peak period (07.30 to 08.30 am) traffic volume of 1,230, 2,202 and 1,794 vehicles per hour respectively at the junctions with the following roads; Souza Lima in the beginning, Santa Clara in the middle and República do Peru at the end of the corridor, before the bus lane construction, from which 368 vehicles were buses, corresponding to 30%, 16% and 20% of the total volume respectively at each of the three junctions. While private cars achieved average operating speed of 19.5 Km-h, the buses achieved only 9.8 Km-h when in mixed traffic conditions, before the implementation of the priority scheme.

After the implementation of the bus lanes that consisted of segregating two of the four lanes for the bus, it was observed an hour traffic volume at the same junctions of 1,086, 1,752 and 1,058 vehicles, from which the bus accounted for 322 vehicles or 29%, 18% and 30% respectively of the total volume. It is interesting to note that the share of the bus remained approximately the same in the two first junctions, but in the last one, the share of the bus went up from 20% to 30% of the total volume, providing evidence that the poorer road performance for the private car may have discouraged its use. Operating speeds for the cars have dropped to 10.6 Km-h, while the bus operating speed increased by 72%, achieving figures as 16.9 Km-h. Table I presents a summary of the speed variation for cars and buses, before and after the bus lane implementation at Nossa Senhora de Copacabana Avenue.

TABLE I

SPEED VARIATION BEFORE AND AFTER THE BUS LANE IMPLEMENTATION- Km-H

	BEFORE (Sep. 1985)	AFTER (Nov. 1985)	VARIATION
CAR	19.5	10.6	- 45.64%
BUS	9.8	16.9	+72.45%

Some advantages of these priority schemes are pointed out; the system capacity can be substantially increased, operating speed may be enhanced (a 50% increase in operating speed may represent time savings of 30% in travelling time in-vehicle), and consequently running costs may be lowered.

The implementation of a bus lane scheme in a corridor of high demand in Rio de Janeiro supported this argument and bus average speeds increased by 72% during the morning peak hours.

So a comprehensive bus priority scheme seems to be a feasible alternative to immediate action in Rio de Janeiro, given the low investments that are necessary and the prompt results.

At this stage, some recommendations regarding the location of these priority corridors are pointed out. From the fieldwork it was possible to detect that the routes operating within the Core were the ones that have presented the lowest figures for operating speed, due to high congestion (as low as 14 Km-H) . So the Core is the priority area where the first improvements should take place, followed by the adjacent areas. By improving services within the core and from this area towards peripheral areas, side effects would be expanded to these areas as well. It may be argued that the implementation of priority schemes in central areas may be contradictory, but peripheral householders do also travel within central areas. So by increasing operating speeds in the Core, in-vehicle travel time of those who live in peripheral areas and work in the Core is also reduced. Some corridors in the Core, Immediate and Intermediate Periphery are selected for priority because of the huge volume of traffic they handle. The bus volume is mainly considered in the following corridors;

Presidente Vargas Avenue.

This is the main corridor within the Central Area, handling heavy flows of public transport. In this corridor operates 89 bus routes (most of them North Radial, Diametrical routes), as well as the underground Line 1. It is 3.5 kilometres long and 85 metres wide.

Aterro do Flamengo.

This corridor comprises six lanes, which were mainly built after successive land reclamations over Guanabara Bay in the early sixties. This corridor is the main access from the Central Area to the Southern zone, although it integrates this zone to the Northern zone as well. It caters for approximately 11% of the total bus volume among the main 24 corridors adopted in the PUB RIO plan.

Francisco Bicalho Avenue.

Although this corridor is not considered among the 24 corridors, it is one of the links between Brazil Avenue and Presidente Vargas Avenue.

Rodrigues Alves Avenue.

This corridor is the other link between Brazil Avenue and Presidente Vargas Avenue. Rodrigues Alves Avenue handles most of the inter city bus traffic as it is located in its extremes both of the main bus terminals in Rio de Janeiro; Mariano Procópio and Novo Rio terminals. It also caters for freight traffic to the port of Rio de Janeiro. It caters for approximately 5% of the bus volume, considering the 24 corridors in PUB RIO.

Barata Ribeiro Street.

This corridor is a binary with Nossa Senhora de Copacabana Avenue, as stated previously in this chapter. Both corridors cater for 4.4% of the total volume of buses in Rio de Janeiro.

Brazil Avenue.

Although there is already one bus lane in this corridor, it is suggested that the priority scheme in operation should be duplicated. Current road capacity does not seem to cope satisfactorily with such a high volume of vehicles, including taxiis, especially during peak periods (as seen in Picture VI).

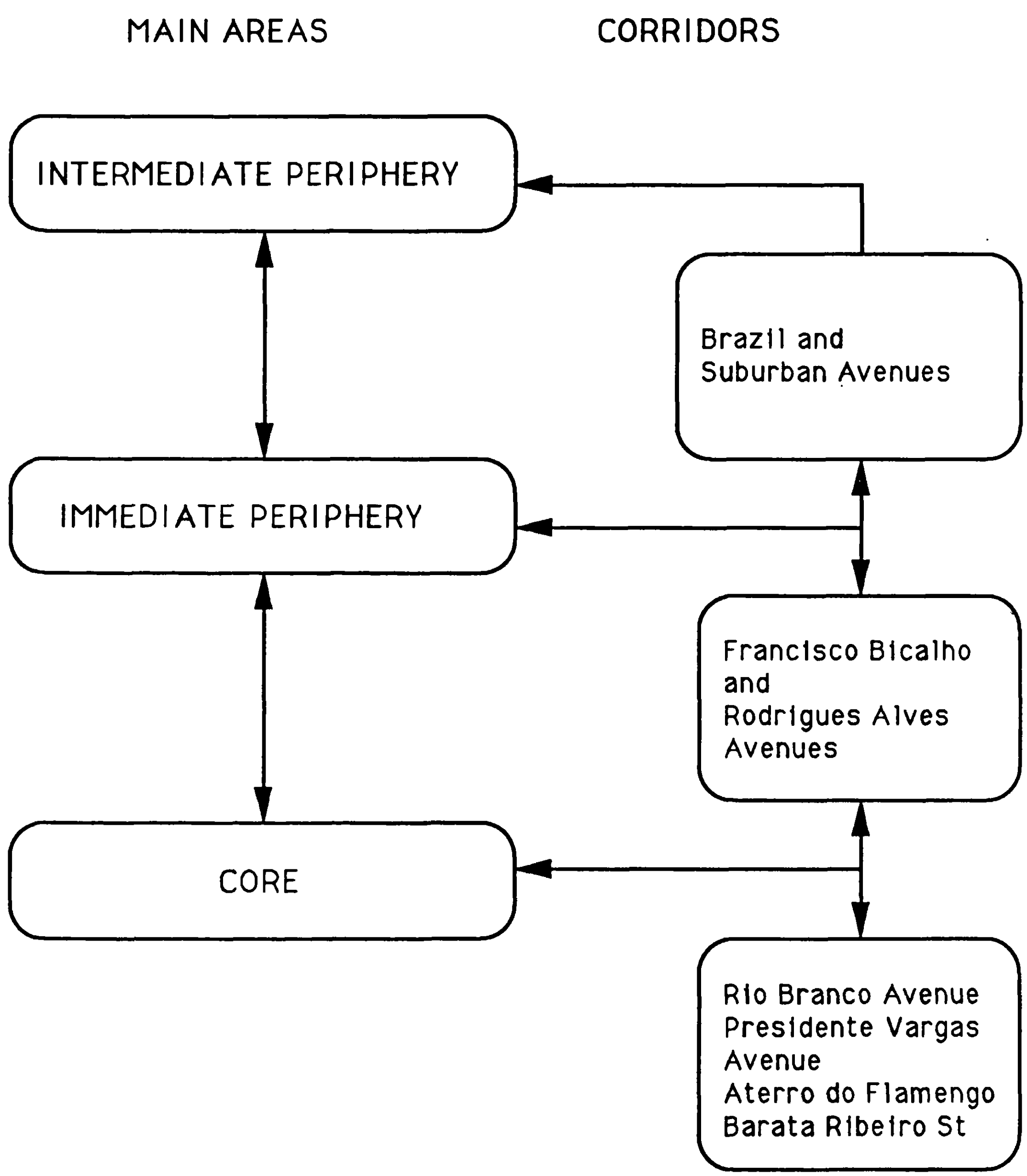
Suburban Avenue.

This corridor is located mainly in industrial areas and it links Ramos borough to Méiier and São Cristóvão boroughs and also to the city centre. It caters for approximately 3% of the total bus volume in Rio de Janeiro. A general scheme of tlhe proposed corridors is shown in Diagram IV and Map VIII.

PHOTOGRAPH VI - A VIEW OF BRAZIL AVENUE BUS LANE

DIAGRAM IV

PROPOSED BUS PRIORITY SCHEMES



These corridors would permit a basic bus lane network which would link with the three first bus lanes already implemented, allowing reductions in in-vehicle travel time by enhancing overall operating speed. The measures already implemented have failed to generate greater benefits because the network is not totally implemented. The gains in speed in some parts of the route with rights of way are offset by roads operating in mixed traffic conditions and heavy traffic volume. So a comprehensive bus lane network could improve operational speeds to a greater extent, also in-vehicle travel time could be reduced, as well as fuel consumption, which certainly would represent savings in running costs, that could be reverted for the passengers or even used to subsidise routes of lower profitability.

VII.2.5- New Fare Structure.

Travel costs were significantly higher for those peripheral dwellers, mainly due to the higher absolute costs of the fares charged mainly in North Radial route types, worsened by the higher number of transfers required to complete their journeys. As stated previously, there is no integrated fare scheme; consequently if a transfer is made another fare must be paid. In addition, the costs of transport have increased significantly along the past years- by 1977 the monthly average commuting costs was approximately 6% of one Minimum Wage; by 1985 this figure was as high as 11.4%, if the passenger lived within the Southern Zone and if he lived in far suburban areas this figure could rise to 40% of the Minimum Wage.

According to Allport (op. cit.), lower fares may give the urban poor wider opportunities for finding work and thus achieving greater economic advancement. Though in general they make fewer trips, mostly only the essential ones, and by the cheapest available alternative. Efficient and cheap public transport is of great importance for them.

According to Chapter III, section III.5.3, the fare levels are set according to the route operating costs, and the demand is considered in such a way that costs are shared equally by all those using the route. This approach on the one hand may increase fares on routes of lower demand or uneven distribution of the demand along the day (in this case peripheral route types apply) and on the other may diminish fare levels on routes of higher demand (in this case routes operating in the core, where demand levels do not present substantial variations along the day). It was shown that there are ten fare categories, and the value charged on a route does not depend on length of the user's journey.

This study suggests that given the fact that peripheral householders were the ones most affected by the high costs of transportation and the ones more likely to interchange, that two measures should be considered; a flat fare throughout the city and a fare integration scheme, allowing as many interchanges as necessary.

A flat fare should be adopted in the Rio de Janeiro bus industry with a respective value corresponding to an intermediate one between the lowest fare presently charged- category I , and the highest one- fare category X. This measure would tradeoff the costs of transport between those less well off and better off more evenly.

However by adopting a higher fare level than the current fare category III (that is charged in 65% of the routes), the costs of transport of a significant number of users may be increased. According to studies developed in 1985 that supported the implementation of flat fares in Rio de Janeiro, the new fare would be set in levels 42% higher than the most representative fare category III, while 37% lower than the fares charged in most of the routes covering Intermediate Periphery and the Core. However, a flat fare scheme would be the only plausible measure to be taken to guarantee that those less well off would have their transport costs alleviated and indirectly subsidised by those better off users who live in more central areas.

In addition the only way of assuring that those living in peripheral areas who travel longer distances are penalised by the lack of direct services to the core should be the adoption of an integrated fare scheme, that would allow them to pay only one fare independently of the number of transfers required or the different modes necessary to reach their final destination.

Finally, considering measures within the bus industry, the travel voucher scheme should be reviewed and become eligible also for those engaged in the informal market, which may represent in urban areas 35% of the total active population and civil servants. The current scheme has failed to achieve its social role by excluding those informally engaged in the labour market and civil servants.

In parallel to all the measures suggested within the three modes of transportation in Rio de Janeiro, it is also recommended that other complementary measures are taken in the long run, such as the decentralisation of the labour market within the Core. It was shown that most of the commuting problems were due to the concentration of the labour market in central areas, and the labour force in peripheral areas.

VII. 3- CONCLUSION.

In this Chapter it was shown that among all the modes of public transport, the bus was the most representative one in terms of demand and also the most flexible one in terms of re-routing services in operation and involved the least amount of investment. For that reason it was suggested that most of the policies should be primarily addressed to improvements within that system. Basically four measures were strongly recommended within the Rio de Janeiro bus transit;

1- The **rationalisation** of the current network and fleet in operation. In this respect the creation of new links between the periphery and the core using other roads was suggested.

2- **Fleet renewal**, that comprised the replacement of the vehicles in operation at present with ones of higher capacity and also the introduction of vehicles with lower capacity such as the minibus for lower density areas or to cover inter peak services.

3- **Priority schemes**, the emphasis is on the implementation of bus lanes in higher capacity corridors, to enhance operating speeds, to reduce operating costs and mainly to reduce in-vehicle travel time, especially between the Intermediate Periphery and the Core.

4- **A new fare structure**, the emphasis on the implementation of a flat fare and integrated schemes, aiming at improving the accessibility of those more affected by the lack of integration within the local bus industry and between the other modes of public transport as well. It was suggested that the travel voucher scheme should be reviewed in order to be more socially effective between lower income groups, who usually are not engaged within the formal market and consequently are not eligible for benefiting of the travel voucher scheme.

Whatever policy or measures are adopted it must be guaranteed that users are not penalised by transferring and paying an additional ticket. In this respect the travel voucher and the integrated fare shemes may play a decisive role in providing a greater mobility of the population, especially if the costs of transportation of those living in distant areas, for whom transport costs may make travelling unaffordable, is taken into account.

Other measures were also suggested in the other two modes of transportation currently in operation in Rio de Janeiro such as the railway and the underground. Both systems were operating far behind the expected demand mainly because of the lack of investment to improve and to complete the network and also the lack of integration with the bus system.

At last the decentralisation of the labour market in spatial terms was suggested in the long run in order to avoid the concentration of demand towards the Core, which in turn requires endless investment and improvements within the transport system to meet the ever increasing demand.

CHAPTER VIII- CONCLUSIONS.

VIII.1- CONCLUSIONS.

The thesis main objective was to investigate how the level of services of public transport varied in Rio de Janeiro according to the socioeconomic spatial distribution of the population, or to what extent the variations in the quality of the services were related to this socioeconomic stratification of the population in spatial terms. So two hypotheses were raised. The first one that the city was spatially socioeconomic segregated, and the second one that the level of services of public transport presented significant variations according to this pattern of spatial distribution of the population.

To validate the first hypothesis some socioeconomic indices were tested among the population in Rio de Janeiro such as income distribution, educational background, car ownership levels, distribution of basic services and tenure. It was clear from the analysis of data from the latest available Census (1980) that both income and wealth were highly concentrated in the Core area, while in peripheral areas was found the concentration of the lower income groups. In addition it was observed how uneven was the distribution of services such as piped water and sewage between dwellings in the Core and peripheral areas.

Also it was observed that the distribution of the activities was such that in the Core was found 60% of the labour market and job opportunities, while 70% of the labour force lived in peripheral areas. As a consequence of this spatial distribution of the labour market and labour force, a pattern of trips was naturally established; the periphery-core link. So the first hypothesis was then validated;

the city of Rio de Janeiro is spatially and socioeconomic segregated, especially if one considers the distribution of welfare.

Then an extensive analysis of all modes of transportation available in Rio de Janeiro was carried out in order to establish not only their main characteristics and catchment areas, but also to have a picture of the role they have played in the Rio de Janeiro urbanization process.

It was shown that two modes of transportation played a decisive role in the spatial socioeconomic segregating process by the turn of this century; While the periphery was developed with the advent of the railway, the wealthy core was with the implementation of the tramway. By that time lower income groups were expelled from the core to the peripheries, while the better off groups remained in the core area where services were extensively provided. So it seemed that since the beginning of this century the poorer areas were neglected to the detriment of the wealthier areas, in terms of public investment and the provision of public services. Since then, the dichotomy between the periphery and the core seemed to have emerged as well as the dependency of the former on the latter.

When analysing the modes of transportation currently in operation in Rio de Janeiro, the bus seemed to be the most representative one, catering for almost 80% of the total demand for public transport. For that reason the bus was selected for further investigation. An extensive survey was carried out on the Rio de Janeiro bus system. The aim of this survey was to get an accurate picture of the system currently in operation on the view of the demand side.

Results from this survey carried out among bus users have demonstrated that the level of inequalities was substantial and greater than expected between services provided within the Core and services provided from peripheral areas to the Core. Those two links seemed to be the most important ones in terms of demand volume.

Among the classic attributes to assess the efficiency of a transit system, **accessibility, comfort and convenience, reliability and safety** seemed to be the ones that allowed some interesting findings. These attributes were assessed mainly by variations in walking time, waiting time, in-vehicle time, travel costs, number of transfers and loading ratios. These were the most important variables in establishing the differences and supporting the fact of how uneven were the access and the provision of these services. This was mainly shown in Chapters V and VI.

Analysing **accessibility,** the figures demonstrated that the access to public transport in Rio de Janeiro was very constrained for those lower income groups. As a result of travelling longer distances, they spent longer time in-vehicle and were charged higher fares in absolute terms. In addition, they were the ones more likely to make interchanges and as they interchanged, a second or even a third fare was to be paid. Their relative costs of transport as a proportion of income were even higher as their income were relatively lower. In central areas the network was denser than in peripheral areas, consequently walking times in these areas were also higher (approximately 70% higher than in the core). As a result, lower income groups and peripheral dwellers might have their use of public transport constrained to trips made only for the purpose of work.

When numbers of **transfers** was considered, 73% and 100% of those respectively catching two or three modes lived in peripheral areas, while if **travel time** was considered, 87% of those travelling for more than 75 minutes (only one way journeys) lived also in peripheral areas providing evidence of how their physical accessibility was constrained in comparison to those living in central areas. When daily **travel costs** in transport are analysed it was shown that while 71% of the core dwellers were able to spend the equivalent of two fares a day (this means no interchange was necessary), 65% of the peripheral ones spent at least the equivalent of six fares daily fare category III, being considered the unitary value of the most common fare charged. So, peripheral householders presented lower accessibility levels both financially and physically than those core householders.

When **comfort and convenience** were analysed, it was also observed that peripheral householders faced poorer services in a comparative basis; their waiting times were up to three times longer than waiting times of those living within the Core and also services presented higher loading ratios (while 67% of those living in both peripheries travelled always seated to the core, 79% of those living and travelling within the core did so). So, waiting time was also affected by the vehicle's crowding. In other words, waiting time seemed to be a function not only of the services headway but also of loading ratios. Periphery-core routes have presented lower turnover, which also contributed to constrain peripheral users to board the first coming bus, while within the core a high turnover was observed. In addition, in peripheral areas there were fewer alternative routes or means of transportation than in central areas, and this factor might also have constrained their access to public transport and to facilities.

The **reliability** of the services also seemed to be poorer in peripheral areas than in the Core. The lower reliability was explained by the longer distances to be overcome, the higher variability in headway due to the longer journeys, which supported previous findings in the literature concerning variation in headway and length of the journey. Waiting time was the variable used to assess reliability of the services, and results were already presented above.

The **safety** of the services was probably the only attribute that did not present significant differences concerning the socioeconomic and spatial segregation of the population. When safety was considered from the point of view of traffic and drivers' behaviour, the system as a whole presented very low safety standards, although no figures were presented for accident rates. From the perspective of assaults on passengers and risk of harassment while in-vehicle, figures have shown that a significant percentage of users have been assaulted (17%) or have seen some others being assaulted (18%) and finally 7% have both seen and been assaulted . It was also mentioned that in 1989 20 to 25 robberies the fare box were registered in Rio de Janeiro every day, not considering incidents involving passengers. Safety seemed to have emerged as a general problem of the system, from both perspectives. In Chapter V the effects of long exposures to high noise levels on individuals health and the long term consequences were also shown, and this might affect drivers' behaviour significantly, which in turn may cause or increase accidents rates or risks of accidents. This point should be developed in further research. The author in particular thinks that the drivers behaviour may be strongly influenced by their adverse working environment.

The poor overall conditions of the service might also have been affected by the lack of integration within the public transport and within the proper bus industry in Rio de Janeiro. In general, the bus industry has been operated by the private sector, and the public sector shared a very low percentage of the market, usually its less profitable segments. As a result of this, a vigorous competition was observed and services were not operated with any rationality. In main corridors overlaps of many routes from different operators were observed, which certainly have led to increases in operating costs and worsening travelling conditions, by increasing travelling time in-vehicles and consequently raising fare levels.

However, recent experiences throughout the country have also shown that services, in general, did not present any improvement when local government took over the operation of their bus industries. Rio de Janeiro was no exception, and the sixteen private operators that were taken over in November 1985 became private again in January 1988 after this initiative did not bring any benefit for the demand side. On the contrary, the system deteriorated substantially in that period, especially the vehicles maintenance, which in turn affected the supply of services significantly mainly within peripheral areas.

The quality of services seemed also to be generally affected by the design of the vehicles currently in operation. They were not appropriate for the purpose of carrying passengers; extremely high steps, poor ventilation coupled with very high interior noise levels and temperatures, worsened by the position of the motor just beside the driver's seat. In addition, the crews' working conditions were also very poor (no facilities were provided at the routes terminals; sometimes no break or rest was possible between two journeys). All these factors seemed to be crucial ones, leading also to the poor conditions of comfort and the low safety standards observed within Rio de Janeiro bus industry. This has put at risk not only the safety of users of the system, but also non users and pedestrians.

When the operators efficiency was analysed it became clear that some economies of scale did exist within Rio's bus industry and also a spatial dimension led for a higher performance and productivity. The profile showed that the most profitable routes seemed to be those shorter ones operating mainly in the Core, where a higher turnover was observed coupled with a more constant demand throughout the day. This was shown in Chapter IV.

Concerning the proposals to improve the overall transport system in Rio de Janeiro, the bus mode has been selected as the priority mode for immediate action. Firstly because it still catered for approximately 80% of the total demand for public transport in Rio de Janeiro and secondly because the it was the most flexible transit and the investment required for improvements within the system were demonstrated to be lower (Chapter VII) in comparison to improvements in other systems or even the implementation of a new transit system, allied to the quick response from the demand side. As travelling time and costs seemed to be the most crucial aspects to those commuters in Rio de Janeiro, especially for those lower income groups, immediate actions are needed to reduce travel times and costs.

Measures were mainly concerned with actions within the organisation, operation and the network redistribution. It is believed that services could be highly improved if a better allocation of the current fleet takes place.

The first measure suggested was the rationalisation of the system, by rationalising the network and allocation of the fleet, avoiding the current savage competition observed between different operators and routes especially in central areas. This measure would certainly incur a better utilisation of the services currently provided, consequently services or the offered supply could be more evenly spread throughout the city and diverted to those areas where demand was poorly serviced. It was suggested that new routes should be created linking peripheral areas to the core using different corridors than the main road currently used (Brazil Avenue).

Given that the most congested corridors had already been identified, priority schemes such as bus lanes were suggested to be implemented progressively, aiming at reducing in-vehicle travel time especially between peripheral areas and the Core and also within the Core, where operating speeds were as low as 14 Km-h during peak periods. The costs of implementation of such schemes were also shown to be attractive in comparison to other alternatives, ranging from US$2 to US$7 million per kilometre. Given that some bus lanes have already been successfully implemented in Rio de Janeiro and operating speeds were increased by approximately 72%, this alternative was highly recommended. This measure would also enhance operators performance and productivity. So, once this aim has been achieved, it might also be expect that fare levels could be lowered, so that users may benefit of those improvements.

The replacement of the current vehicles by ones of higher capacity were suggested as an alternative to improve overall comfort and safety conditions in corridors of high demand as well as the implementation of alternative services such as the minibus in areas of lower demand or difficult access. The fleet replacement should be considered in conjunction with the rationalisation of the system just mentioned above. Increases in the system capacity and the penetration of services in areas not been served before would also increase accessibility in areas less well serviced as well as the mobility of the population.

To tackle the problem of the lower accessibility of peripheral dwellers, some measures were suggested aiming at minimising their transport costs, such as a new fare structure. A flat fare structure was suggested as the most appropriate, coupled with a comprehensive integration fare scheme, guaranteeing that users who interchanged would not be penalised by paying additional fares. Some review of the travel voucher scheme was also suggested, such as the inclusion of those engaged in the informal market, that may represent up to 35% of the active population and civil servants.

Parallel to all those improvements suggested within the bus system, attention was also addressed to improvements within the railway system to recover its potential demand that has switched to the bus as a consequence of the system's current poor operating conditions. The importance of improvements within this system lies in the fact that the railway demand consists mainly of peripheral lower income groups.

The underground completion was also suggested as an essential measure , as its partial construction had not justified the huge amount of investment already allocated and the low benefits brought to the population as a whole. Current demand was far from reaching the target demand (half of it), and its partial operating network seemed to be contributing to this failure of the system. The completion of this rapid transit would also enable the bus industry to diminish its high share within the public transport system, which would certainly generate benefits for the whole system. Also it could attract those currently using private transport, consequently improving traffic conditions substantially.

Finally the recommendations for further research suggests that accident rates involving buses should be studied and also if these accidents are caused by the poor working conditions of the bus crew. The working conditions seemed to be one of the most important factors that, although not expected, might have affected the quality and the safety of the operating services. In this respect, the inappropriateness of the vehicles in operation played a decisive role in affecting the level of services, irrespective of the spatial dimension or the socioeconomic distribution of the population; all segments seemed to be equally and significantly affected.

The results presented throughout this work should be used as a starting point in order to set up minimum standards for the operation of the system under safer conditions. Noise level and temperature exposures should be kept within acceptable levels, and vehicles should be substituted for those of higher technology, capacity and comfort conditions.

In addition, some experimental programmes should be developed aimed at being tested within peripheral areas, such as the proposed bus lane schemes, new fare structures and even a subsidy scheme.

Finally is believed that services in Rio de Janeiro will not improve unless significant improvements take place in the working conditions of the bus industry crew, especially the drivers. If this goal is achieved all users will benefit from a more comfortable and safer system.

APPENDICES

APPENDICES

The first appendix is related to the survey questionnaire which is divided into two parts; the first one the journey questionnaire while the second one the users questionnaire which is in turn, divided also in two parts: the first one related to the users socioeconomic status and the second one referred to their travelling pattern. As explained in Chapter V, the sample size was 554 users, selected randomly in the fifteen routes surveyed. The survey was carried out from September the 27th to November the 1st, 1989. On the total 228 trips were carried out, from Mondays to Fridays.

Appendix II presents data referring to some performance indicators of the bus operators in Rio de Janeiro, like fleet in operation, supply, demand, number of trips carried out, kilometres run, revenues, referring to the period from January to October, 1988. These variables allowed to setting some indicators such as loading factor, revenues per kilometre, per trip, per passenger, kilometre passenger index (KPI) and trip passenger index (TPI) among others. Appendix III presents a correlation matrix of these variables presented in Appendix II.

Appendix IV, similarly to Appendix II, presents some performance indicators, but aggregated by route type. At this stage not all routes were considered in the analysis, as explained in Chapter V. Appendix V, presents the matrix correlation of the variables presented in Appendix IV.

Appendix VI, presents also the same performance indicators presented in Appendices II and IV, but only to the routes surveyed, followed by the

Capital and operating costs may play a decisive role in the planning decision making process. Once the deficiencies in the transit system are detected and the priorities defined one must be concerned about the scale of the investments necessary to implement the proposed measures to improve the system performance.

A summary of the investment required, according to infrastructure and equipment, vehicles, and total costs related to all the options of transits are shown in Table I, Appendix VIII, in order to allow a scale of magnitude in respect to the amount of investment necessary to the development and implementation of these different alternatives. Table II, Appendix IX, presents the costs involved with vehicle acquisition, including vehicle capacity, purchase price, price per seat and also vehicles life span, while Table III, Appendix X, presents the total system cost for implementation of different transits, ranging from bus in mixed traffic conditions to rapid rail and underground.

Appendix XI presents the evaluation of the bus system in Rio de Janeiro according to the transport expert's point of view and a scale that includes five categories; very good, good, fair, bad and poor. Table I presents the vehicle's hygiene and maintenance, Table II the traffic conditions and Table III drivers, conductors and passengers' behaviour.

No.______
Date:___/___/____

I- JOURNEY QUESTIONNAIRE:

1. DATA REFERING TO THE ROUTE:

1.1- Route Number:_______ 1.2- Direction:______________________
1.3- Operator:___________________
1.4- Number of Stops:_______
1.5- Route Type I:

1. North Radial ☐ 2. South Radial ☐ 3. Diametrical ☐
4. North Local ☐ 5. South Local ☐

1.6- Route Type II: 1. Circular ☐ 2. Non circular ☐
1.7- Operating Period:________/__________

2. DATA REFERING TO THE VEHICLE:

2.1- Year of Fabrication:_______
2.2- Capacity- seatead:________ standing:________
2.3- Floor Area:__________ 2.4- Ventilation Area:___________
2.5- Steps Height- boarding:______/______/______
alighting:______/______/______
2.6- Doors Width- boarding:_______
alighting:_______

3. DATA REFERING TO THE JOURNEY:

Time of-
3.1- departure:______ 3.2- arrival:_______ 3.3-journey time:_______
Passenger Metre-
3.4- departure:_______3.5- arrival:_______ 3.6- demand:_______pass
Speedmetre-
3.7-at origin:________3.8-at destination:_______3.9-trip length:____km

3.10- For the following questions, evaluate the items according to the scale:
VG or VH - very good or very high; G or H - good or high; F - Fair
B or L - bad or low; P or VL - poor or very low

	VG-VH	G-H	F	B-L	P-VL
1. Noise level	☐	☐	☐	☐	☐
2. Vehicle Maintenance and Hygiene	☐	☐	☐	☐	☐
3. Traffic Conditions	☐	☐	☐	☐	☐
4. Driver's Behaviour	☐	☐	☐	☐	☐
5. Conductor's Behaviour	☐	☐	☐	☐	☐
6. Passenger's Behaviour	☐	☐	☐	☐	☐

II-USERS QUESTIONNAIRE

1. SOCIOECONOMIC DATA:

1.1- Sex 1. M ☐ 2. F ☐

1.2- Age:_____

1.3- Address:

Home:________________

Work:________________

Study:________________

1.4- Educational Background:

1. Illiterate ☐ 2. Primary School ☐
3. Secondary School ☐ 4. Higher Degree ☐

1.5- Occupation:_____________

1.6- Monthly Income:

1. NCZ$_________ 2.No income ☐ 3. Did not declare ☐

1.7- Household Car Ownership:

No ☐ Yes ☐

1.8- Access to use the car

No ☐ Yes ☐

1.9- How often? 1. Weekend ☐ 2. Evenings ☐ 3. Eventually ☐

1.10- Tenure: 1. Owneroccupier ☐ 2. Tenant ☐ 3. Other ☐

2. TRAVELLING PATTERN:

2.1- Purpose: 1. Work ☐ 2. Study ☐ 3. Entertainment ☐

4. Shopping ☐ 5. Medical ☐ 6. Others ☐

2.2- Direction: 1. Going ☐ 2. Coming ☐

2.3- How many modes do you use to make this specific journey?

1. One ☐ 2. Two ☐ 3. Three ☐ 4. Other ☐

2.4- In case of transfer, what other modes do you use?

1. Bus ☐ Route Number:_____ 2. Underground ☐

3. Train ☐ 4. Boat ☐ Place of transfer:____________

2.5 How often do you travel by public transport (days a week)?

1. One ☐ 2. Two ☐ 3. Three ☐
4. Four ☐ 5. Five ☐ 6. More ☐

2.6- How many minutes, on average, does it take you to?

1. Walk to the bus stop?__________
2. Wait for the bus?__________
3. Travel in-vehicle?__________
In case of transfer:
4. Walk at the transfer?__________
5. Wait?__________
6. Travel in the second mode?__________

2.7- Do you usually travel: seated ☐ standing ☐

2.8- At what time do you usually catch the bus?
1- To go to work:__________ 2. To come back home:__________

2.9- What is your daily cost with transport?

1. NCZ$__________ 2. Two fares ☐ 3. Three fares ☐

4. Four fares ☐ 5. Other:__________

Are you a travel voucher holder? Yes ☐ No ☐

2.10- For the following question, answer according to the scale:
VG- very good G- good F- fair B- bad P- poor

	VG	G	F	B	P
1. Cleaniness	☐	☐	☐	☐	☐
2. Comfort	☐	☐	☐	☐	☐
3. Reliability	☐	☐	☐	☐	☐
Frequency					
4. Daytime	☐	☐	☐	☐	☐
5. Evenings	☐	☐	☐	☐	☐
6. Weekends	☐	☐	☐	☐	☐
7. Drivers Behaviour	☐	☐	☐	☐	☐
8. Conductors Behaviour	☐	☐	☐	☐	☐
9. Traffic Conditions	☐	☐	☐	☐	☐
10. Operating Hours	☐	☐	☐	☐	☐

VH- very high H- high F- fair L- low VL-very low

	VH	H	F	L	VL
11. Fare	☐	☐	☐	☐	☐
12. Assault Risk	☐	☐	☐	☐	☐
13. Safety (driver)	☐	☐	☐	☐	☐

2.11.Have you ever been assaulted? Yes ☐ No ☐

2.12. Orwitnessed an assault? Yes ☐ No ☐

2.13.Or even both? Yes ☐ No ☐

2.14- In your opinion what sort of measures could be adopted to improve the bus system generally?

1. Increase frequency ☐ 2. Schedule services ☐

3. Fleet renewal ☐ 4. Better trained crew ☐

5. Better vehicle maintenance ☐ 6. Cleaner vehicles ☐

7. Others:______________________

2.15- If any of the measures you have suggested were adopted, would you be willing to pay higher fares?

1. No ☐ 2. Yes ☐ 3. NCZ$________(state value)

2.16- Do you usually travel by other modes of transportation than the bus?

1. No ☐ 2. Yes ☐

In case of a negative answer do not consider the next two questions

2.17- Which one? 1. Underground ☐ 2. Train ☐ 3. Boat ☐

2.18- In your opinion which offers the best service, including the proper bus?

1. Bus ☐ 2. Underground ☐ 3. Train ☐ 4. Boat ☐

Reason

1. Safer ☐ 2. Quicker ☐ 3. Cleaner ☐ 4. More Comfortable ☐

2.19- Do you have another alternative bus route or mode of transportation to make this specific trip?

1. No ☐ 2. Yes ☐

In case of a negative answer do not consider the next two questions

2.20- Which one?

1. Bus ☐ route numbers:________________

2. Underground ☐ 3. Train ☐

2.21- What was the criteria that you have used to travel in this specific route?

1. Shorter walking distance to the stop ☐

2. Shorter waiting times ☐

3. Higher frequency ☐

4. Direct service or no need to interchange ☐

5. Shorte in-vehicle time ☐

6. Less risk of assault ☐

7. Services are more reliable ☐

8. Drivers behaviour ☐

9. More comfortable ☐

10. Cheaper ☐

2.19- Would like to make any comments?________________________
____
____
____

GENERAL COMMENTS:____
____
____
____

APPENDIX II- OPERATORS PERFORMANCE INDICATORS- JAN./OCT. 1988

	A	B	C	D	E	F
1	OPERATOR	FLEET SIZE	PASSENGERS	SUPPLY	TRIPS MADE	KILOMETRE RUN
2	TIJUCA	120	21849728	37218090	287093	9144125
3	PAVUNENSE	120	29846118	32711570	257695	10159993
4	A.MATIAS	120	22724896	33763413	264282	9280993
5	IDEAL	120	21130105	25166700	193590	8810733
6	ACARI	120	22209187	32718140	251678	9654058
7	RUBANIL	123	22979387	28160440	217900	9639038
8	ESTRELA AZUL	124	24037844	27289600	209920	9641467
9	NOVACAP	125	26557729	25415000	195500	10528541
10	ESTRELA	125	20635750	38380290	295233	10282595
11	PARAENSE	126	15792515	18507580	143056	8615075
12	CAPRICHOSA	127	32050928	42889672	332724	9558087
13	ALPHA	132	23685655	37455340	288116	11346998
14	SANTA MARIA	133	29735079	41441740	318798	10828565
15	AMERICA	134	17865144	25766910	196078	10639662
16	BRASO LISBOA	135	22710212	33126970	254869	11295321
17	N.S.LOURDES	138	31706863	34633290	266487	10516749
18	PEGASO	141	5047288	10345270	78779	10957191
19	CAMPO GRANDE	141	25522941	28464138	224145	11356610
20	VILA ISABEL	156	26252575	31831410	244857	11809581
21	TRES AMIGOS	161	39993116	58178610	455145	13162157
22	MOSA	167	24805935	47646040	366508	12777979
23	M.CANDELARIA	168	25581209	31741266	235785	12188003
24	JABOUR	169	38278997	61931870	476399	17394296
25	PARANAPUAN	201	42570468	40420900	310930	14481936
26	AMIGOS UNIDOS	210	37328535	69736550	531348	17413222
27	ORIENTAL	223	38673948	47578700	365590	21539071
28	BANGU	225	48807634	59483270	457479	18973125
29	SAO SILVESTRE	260	49712315	78627120	604824	16292017
30	REAL	266	48326309	74455746	523448	18401757
31	VERDUN	319	71792873	70994815	546113	21663301
32	REDENTOR	336	58624961	72730468	559329	27372509
33	AUTO DIESEL	346	56241613	61118720	470144	25998097

	G	H	I	J	K	L	M
1	REVENUES	LOAD FACTOR	REV-KM	REV-PASS	REV-TRIP	KPI	TPI
2	782148507	0.59	85.54	35.8	2724.37	2.39	76.11
3	1010391960	0.91	99.45	33.85	3920.88	2.94	115.82
4	780580472	0.67	84.11	34.35	2953.59	2.45	85.99
5	619174804	0.84	70.28	29.3	3198.38	2.4	109.15
6	756700920	0.68	78.38	34.07	3006.62	2.3	88.24
7	754635968	0.82	78.29	32.84	3463.22	2.38	105.46
8	830223188	0.88	86.11	34.54	3954.95	2.49	114.51
9	933930363	1.04	88.7	35.17	4777.14	2.52	135.85
10	753023406	0.54	73.23	36.49	2550.61	2.01	69.9
11	760789553	0.85	88.31	48.17	5318.12	1.83	110.39
12	1016647214	0.75	106.37	31.72	3055.53	3.35	96.33
13	842936311	0.63	74.29	35.59	2925.68	2.09	82.21
14	1012657068	0.72	93.52	34.06	3176.49	2.75	93.27
15	863070292	0.69	81.12	48.31	4401.67	1.68	91.11
16	812241598	0.69	71.91	35.77	3186.9	2.01	89.11
17	1066535271	0.92	101.41	33.64	4002.2	3.01	118.98
18	538621913	0.49	49.16	106.72	6837.13	0.46	64.07
19	1082592807	0.9	95.33	42.42	4829.88	2.25	113.87
20	906650442	0.82	76.77	34.54	3702.78	2.22	107.22
21	1320465326	0.69	100.32	33.02	2901.2	3.04	87.87
22	843899422	0.52	66.04	34.02	2302.54	1.94	67.68
23	1000023235	0.81	82.05	39.09	4241.25	2.1	108.49
24	1246778342	0.62	71.68	32.57	2617.09	2.2	80.35
25	1346866312	1.05	93	31.64	4331.73	2.94	136.91
26	1407993811	0.54	80.86	37.72	2649.85	2.14	70.25
27	1768234598	0.81	82.09	45.72	4836.66	1.8	105.79
28	1685498351	0.82	88.84	34.53	3684.32	2.57	106.69
29	1672384569	0.63	102.65	33.64	2765.08	3.05	82.19
30	1726604427	0.65	93.83	35.73	3298.52	2.63	92.32
31	2518306926	1.01	116.25	35.08	4611.33	3.31	131.46
32	2505219836	0.81	91.52	42.73	4478.97	2.14	104.81
33	2219661482	0.92	85.38	39.47	4721.24	2.16	119.63

	N	O	P
1	KM-VEHICLE	REV-VEHICLE	PASS-VEHICLE
2	76201.04	6517904.22	182081.07
3	84666.61	8419933	248717.65
4	77341.61	6504837.27	189374.13
5	73422.77	5159790.03	176084.21
6	80450.48	6305841	185076.56
7	78366.16	6135251.77	186824.28
8	77753.77	6695348.29	193853.58
9	84228.33	7471442.9	212461.83
10	82260.76	6024187.25	165086
11	68373.61	6038012.33	125337.42
12	75260.53	8005096.17	252369.51
13	85962.11	6385881.14	179436.78
14	81417.78	7613962.92	223572.02
15	79400.46	6440823.07	133321.97
16	83669.04	6016604.43	168223.79
17	76208.33	7728516.46	229759.88
18	77710.57	3820013.57	35796.37
19	80543.33	7677963.17	181013.77
20	75702.44	5811861.81	168285.74
21	81752.53	8201647.99	248404.45
22	76514.84	5053289.95	148538.53
23	72547.64	5952519.26	152269.1
24	102924.83	7377386.64	226502.94
25	72049.43	6700827.42	211793.37
26	82920.1	6704732.43	177754.93
27	96587.76	7929303.13	173425.78
28	84325	7491103.78	216922.82
29	62661.6	6432248.34	191201.21
30	69179.54	6490994.09	181677.85
31	67910.03	7894379.08	225056.03
32	81465.8	7456011.42	174479.05
33	75139.01	6415206.6	162548.01

Correlation Matrix for Variables: X_1 ... X_{15}

	FLEET SI...	PASSEN...	SUPPLY	TRIPS M...	KILOMET...	REVENUES	LOAD FA...	REV-KM
FLEET SIZE	1							
PASSENG...	.858	1						
SUPPLY	.832	.93	1					
TRIPS M...	.824	.93	1	1				
KILOMET...	.972	.809	.831	.824	1			
REVENUES	.963	.958	.9	.897	.932	1		
LOAD FA...	-.165	.073	-.284	-.279	-.286	-.033	1	
REV-KM	.226	.649	.457	.465	.097	.448	.581	1
REV-PASS	-.103	-.592	-.505	-.517	-.06	-.344	-.387	-.858
REV-TRIP	-.152	-.529	-.668	-.678	-.181	-.324	.223	-.526
KPI	.111	.594	.459	.469	.012	.349	.492	.959
TPI	-.126	.1	-.261	-.257	-.25	.001	.999	.583
KILOMET...	-.381	-.372	-.158	-.15	-.157	-.359	-.441	-.486
REV-VEHI...	-.003	.492	.384	.398	-.026	.266	.45	.867
PASS-VE...	-.028	.488	.404	.417	-.068	.23	.408	.865

Correlation Matrix for Variables: X_1 ... X_{15}

	REV-PASS	REV-TRIP	KPI	TPI	KILOMET...	REV-VEH...	PASS-V...
REV-PASS	1						
REV-TRIP	.81	1					
KPI	-.958	-.701	1				
TPI	-.379	.234	.487	1			
KILOMET...	.084	-.202	-.316	-.469	1		
REV-VEHI...	-.927	-.689	.915	.434	.011	1	
PASS-VE...	-.981	-.783	.959	.393	-.038	.967	1

APPENDIX IV- PERFORMANCE INDICATORS BY ROUTE TYPES- JAN/OCT. 1988

	A	B	C	D	E	F	G
1	ROUTE TYPE	COUNT	FLEET	TRIP LENGTH	RUN.TIME	OP.SPEED	PASSENGERS
2	NORTH RADIAL	50	21	33 KM	65 MIN.	27 KM/H	3227884
3	NORTH LOCAL	107	16	25 KM	68 MIN.	22 KM/H	3429362
4	DIAMETRICAL	22	25	22 KM	59 MIN.	23 KM/H	4890275
5	SOUTH RADIAL	20	19	22 KM	58 MIN.	21 KM/H	3438449
6	SOUTH LOCAL	21	12	23 KM	78 MIN.	18 KM/H	2194878

	H	I	J	K	L	M
1	SUPPLY	TRIPS MADE	KILOMETRE RUN	REVENUES	FARE	LOAD FACTOR
2	4230629	32074	1784944	CZ$144222	CZ$0.216	0.728
3	4259431	32812	1245143	CZ$117758	CZ$0.137	0.767
4	5821434	42773	1990555	CZ$177410	CZ$ 0.141	0.842
5	5561127	40343	1338804	CZ$125708	CZ$0.140	0.605
6	3853868	30229	755980	CZ$74194	CZ$0.139	0.522

	N	O	P	Q	R	S	T
1	REV-KM	REV-PASS	REV-TRIP	KPI	TPI	SEAT-KM	KM-VEHICLE
2	CZ$0.081	CZ$0.052	CZ$4.73	1.87	96	2.6	90119
3	CZ$0.097	CZ$0.036	CZ$3.52	2.94	100	4.2	76908
4	CZ$ 0.94	CZ$0.037	CZ$4.09	2.54	112	3.3	80766
5	CZ$0.920	CZ$0.053	CZ$2.96	2.43	77	4.5	70403
6	CZ$0.090	CZ$0.034	CZ$2.21	2.66	65	5.1	63144

APPENDIX V- PERFORMANCE INDICATORS MATRIX BY ROUTE TYPE- JAN/OCT 1988

Correlation Matrix for Variables: $X_1 \dots X_{20}$

	fleet	trip length	running ...	operatio...	passeng...	supply	trips ma...	kilometr...
fleet	1							
trip length	.131	1						
running ti...	-.845	.115	1					
operation...	.728	.731	-.543	1				
passengers	.898	-.199	-.818	.501	1			
supply	.759	-.487	-.892	.186	.826	1		
trips made	.75	-.517	-.874	.161	.837	.998	1	
kilometre...	.978	.31	-.765	.84	.848	.613	.603	1
revenues	.988	.137	-.83	.752	.931	.725	.721	.982
fare	.3	.953	-.031	.758	-.099	-.293	-.329	.44
load factor	.766	.184	-.566	.71	.853	.422	.436	.827
rev-km	-.112	-.801	-.139	-.462	.328	.336	.374	-.205
rev-pass	.354	.453	-.533	.531	.018	.251	.197	.348
rev-trip	.756	-.315	-.497	.23	.862	.688	.715	.693
kpi	-.448	-.721	.251	-.65	-.008	-.032	.011	-.504
tpi	.787	.21	-.581	.735	.855	.429	.441	.849

Correlation Matrix for Variables: $X_1 \dots X_{20}$

	fleet	trip length	running ...	operatio...	passeng...	supply	trips ma...	kilometr...
seat-km	-.789	-.696	.478	-.959	-.549	-.207	-.189	-.894
km-vehicle	.717	.743	-.455	.986	.506	.125	.107	.843
rev-vehi...	.754	.135	-.65	.702	.862	.478	.489	.802
pass-veh...	-.163	-.646	-.008	-.378	.285	.154	.196	-.204

APPENDIX V- PERFORMANCE INDICATORS MATRIX BY ROUTE TYPE- JAN/OCT 1988

Correlation Matrix for Variables: $X_1 \ldots X_{20}$

	revenues	fare	load fact...	rev-km	rev-pass	rev-trip	kpi	tpi
revenues	1							
fare	.265	1						
load factor	.855	.157	1					
rev-km	-.026	-.912	.201	1				
rev-pass	.272	.589	-.092	-.585	1			
rev-trip	.765	-.175	.683	.265	-.296	1		
kpi	-.356	-.894	-.023	.923	-.762	.038	1	
tpi	.871	.192	.999	.163	-.057	.682	-.066	1
seat-km	-.799	-.766	-.728	.518	-.404	-.411	.69	-.755
km-vehicle	.75	.759	.754	-.459	.401	.298	-.617	.777
rev-vehi...	.846	.097	.983	.277	-.014	.612	.024	.981
pass-veh...	-.048	-.816	.296	.965	-.692	.231	.943	.255

	seat-km	km-vehi...	rev-veh...	pass-ve...
seat-km	1			
km-vehicle	-.98	1		
rev-vehicle	-.674	.72	1	
pass-vehicle	.433	-.347	.352	1

APPENDIX VI- SURVEYED BUS ROUTES PERFORMANCE INDICATORS- JAN/OCT 1988

	A	B	C	D	E	F	G
1	ROUTE	TYPE ONE	TYPE TWO	FLEET	PASSENGERS	SUPPLY	TRIPS MADE
2	125	SOUTH RADIAL	NON CIRCULAR	37	8431720	10462725	80482
3	127	SOUTH RADIAL	NON CIRCULAR	29	7368094	8594300	66236
4	175	SOUTH RADIAL	CIRCULAR	24	4610187	6155604	39459
5	240	NORTH RADIAL	NON CIRCULAR	18	1617761	2645825	20352
6	261	NORTH RADIAL	NON CIRCULAR	20	6638926	6240550	32845
7	394	NORTH RADIAL	NON CIRCULAR	24	2854837	3640910	28007
8	415	DIAMETRICAL	NON CIRCULAR	32	6877859	8346130	64201
9	434	DIAMETRICAL	NON CIRCULAR	43	9029555	7954050	61185
10	484	DIAMETRICAL	NON CIRCULAR	35	5814977	5881070	45239
11	512	SOUTH LOCAL	CIRCULAR	12	2108767	3808870	29299
12	574	SOUTH LOCAL	CIRCULAR	11	1853813	3285620	25274
13	591	SOUTH LOCAL	CIRCULAR	18	3715736	5495750	42269
14	606	NORTH LOCAL	NON CIRCULAR	48	9453623	12668760	97452
15	634	NORTH LOCAL	NON CIRCULAR	37	8261987	5815030	44731
16	638	NORTH LOCAL	NON CIRCULAR	54	11143123	10430420	80234

	H	I	J	K	L	M	N	O	P
1	KM RUN	REVENUES	FARE	LOAD FACTOR	REV-KM	REV-PASS	REV-TRIP	KPI	TPI
2	2575504	296380	0.14	0.81	0.115	0.035	3.68	3.27	105
3	2312050	251194	0.14	0.86	0.109	0.034	3.79	3.19	111
4	2664670	247002	0.22	0.75	0.093	0.054	6.26	1.73	116
5	1322900	106122	0.27	0.61	0.081	0.066	5.21	1.22	79
6	2096562	310532	0.14	1.06	0.148	0.047	9.45	3.17	202
7	2548637	188992	0.29	0.78	0.074	0.066	6.75	1.12	101
8	3595256	247000	0.14	0.82	0.069	0.036	3.85	1.91	107
9	3456953	313565	0.14	1.14	0.091	0.035	5.12	2.61	148
10	2578623	197116	0.14	0.99	0.076	0.034	4.36	2.26	129
11	791073	71817	0.14	0.55	0.091	0.034	2.45	2.67	72
12	603802	62865	0.14	0.56	0.104	0.034	2.49	3.07	73
13	1225801	132027	0.14	0.68	0.108	0.036	3.12	3.03	88
14	3508272	328844	0.14	0.75	0.094	0.035	3.37	2.69	97
15	2862784	283799	0.14	1.42	0.099	0.034	6.34	2.89	185
16	3987620	375036	0.14	1.07	0.094	0.034	4.67	2.79	139

	Q	R	S	T
1	SEAT-KM	KM-VEHICLE	REV-VEHICLE	PASS-VEHICLE
2	4.06	69608	8010	227884
3	3.72	79726	8661	254072
4	2.31	111028	10291	192091
5	2	73494	5895	89876
6	2.98	104828	15526	331946
7	1.43	106193	7874	118952
8	2.32	112352	7718	214933
9	2.3	80394	7292	209990
10	2.28	73675	5631	166142
11	4.81	65923	5984	175731
12	5.44	54891	5715	168528
13	4.48	68100	7334	206430
14	3.61	73089	6850	196950
15	2.03	77373	7670	223297
16	2.62	73845	6945	206354

APPENDIX VII- SURVEYED ROUTES PERFORMANCE INDICATORS MATRIX

Correlation Matrix for Variables: X_1 ... X_{17}

	OF	PASSEN...	SUPPLY	TRIPS M...	KM RUN	REVENUES	FARE	LF
OF	1							
PASSENG...	.918	1						
SUPPLY	.823	.885	1					
TRIPS M...	.843	.859	.983	1				
KM RUN	.906	.848	.746	.731	1			
REVENUES	.852	.938	.814	.745	.884	1		
FARE	-.295	-.522	-.497	-.486	-.133	-.284	1	
LF	.602	.689	.295	.257	.612	.696	-.297	1
REV/KM	-.154	.182	.147	.024	-.233	.234	-.403	.167
REV/PASS	-.357	-.508	-.501	-.536	-.159	-.223	.96	-.249
REV/TRIP	.027	.12	-.143	-.276	.245	.407	.361	.534
KPI	.145	.43	.412	.383	-.082	.247	-.86	.235
TPI	.386	.569	.211	.101	.471	.676	-.258	.9
SU/KM	-.384	-.223	.017	.037	-.596	-.412	-.529	-.531
KM/OF	.015	.064	.02	-.08	.423	.338	.384	.197
REV/OF	-.106	.18	.101	-.072	.113	.421	-.026	.294
PASS/VE	.186	.55	.465	.343	.237	.564	-.664	.467

	REV/KM	REV/PA...	REV/TRIP	KPI	TPI	SU/KM	KM/OF	REV/OF
REV/KM	1							
REV/PASS	-.202	1						
REV/TRIP	.33	.541	1					
KPI	.73	-.795	-.237	1				
TPI	.447	-.101	.767	.263	1			
SU/KM	.43	-.534	-.652	.67	-.468	1		
KM/OF	-.101	.487	.662	-.496	.375	-.64	1	
REV/OF	.704	.214	.772	.19	.651	-.159	.625	1
PASS/VE	.774	-.479	.324	.722	.662	.192	.215	.742

APPENDIX VIII

TABLE I

TRANSIT SYSTEM INFRASTRUCTURE AND FIXED EQUIPMENT COSTS

(FOR TWO LANES OR TWO TRACKS IN US$ MILLIONS)

Infrastructure			**Transit**		
	Busway	Tramway	LRT	Rapid Rail	Life Span
Elevated structure(km)	-	-	20-40	20-40	40-60
Tunnel (km)	-	-	60-90	60-90	100
Segregated roadway (km)	2.0-7.0	-	1.5-5.5	5-10	40-60
Track (km)	-	1.0-2.0	1.0-2.0	1.0-1.5	20-35
Signals (km)	-	-	0.5-1.0	1.0-5.0	20-30
Power (km)	-	2.5-3.0	2.5-3.0	1.0-3.0	30-35
Stations					
Surface (Ea.)	<0.05	<0.05	0.1-0.15	0.2-0.5	40-60
Elevated (Ea.)	-	-	1.0-3.0	2.0-5.0	40-60
Underground (Ea.)	-	-	4.0-10.0	8.0-20	100
Yards (Ea.)	5-20	5-20	10-40	10-40	40-60
Workshops (Ea.)	10-30	10-30	15-50	15-50	40-60

SOURCE: WORLD BANK TECHNICAL PAPER NUMBER 52, 1986.

APPENDIX IX

TABLE II

VEHICLE COSTS

Vehicle	Capacity Seated	Capacity total	Purchase Price (US$)	Price per seat (US$)	Life Span in years
BUS INDUSTRY					
Minibus	12	18	25,000	2,100	8
Small bus	20	30	40,000	2,000	10
Standard bus	40	80	50,000	1,250	12
Large single deck bus	50	100	80,000	1,600	15
Large double deck bus	80	120	100,000	1,250	15
Super large double deck bus	80	170	120,000	1,500	15
Articulated bus	55	120	130,000	2,350	15
Super articulated bus	55	190	150,000	2,700	15
RAIL INDUSTRY (Vehicles)					
Trams	60	100	300,000	5,000	20
Light Rail	50	300	800,000	16,000	25
Rapid Rail	50	350	1,000,000	20,000	30

SOURCE: WORLD BANK TECHNICAL PAPER NUMBER 52, 1986.

APPENDIX X

TABLE III

TOTAL SYSTEM COST

System	Cost per Passenger-km (in US$)
Bus in mixed traffic	0.02-0.05
Bus in reserved lane	0.02-0.05
Bus in expressway	0.05-0.08
Tramway	0.03-0.10
Rapid rail- surface	0.10-0.15
Rapid rail- elevated	0.12-0.20
Rapid rail- underground	0.15-0.25

SOURCE: WORLD BANK TECHNICAL PAPER NUMBER 52, 1986.

APPENDIX XI

QUALITATIVE EVALUATION- TRANPORT EXPERTS' POINT OF VIEW

I- VEHICLE HYGIENE AND MAINTENANCE

Category	Frequencies	
Very good	8	3.5%
Good	67	29.4%
Fair	87	38.2%
Bad	55	24.1%
Poor	9	3.9%
Missing	2	0.9%

II- TRAFFIC CONDITIONS

Categories	Frequencies	
Good	63	27.6%
Fair	90	39.5%
Bad	39	17.1%
Poor	31	13.6%
Missing	5	2.2%
Total	228	100%

III- DRIVERS, CONDUCTORS AND PASSENGERS BEHAVIOUR

Categories	Frequencies					
	Drivers		Conductors		Users	
Very Good	11	4.8%	110	48.2%	112	49.1%
Good	95	41.7%	106	46.5%	104	45.6%
Fair	67	29.4%	6	2.6%	4	1.8%
Bad	39	17.1%	-	-	1	0.4%
Poor	11	4.8%	1	0.4%	2	0.9%
Missing	5	2.2%	5	2.2%	5	2.2%
Total	228	100%	228	100%	228	100%

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