BRAZILIAN RAILWAYS: AN APPLICATION OF COST ANALYSIS

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ABSTRACT

It is widely argued that rail transport is cheaper, safer and more sustainable than using the road transport. However, the Brazilian railway system faces many problems such as right-of-way invasion, critical level crossing and logistical bottlenecks. The use of techniques, as the Economic Analysis of Projects, is essential to help the decision makers to better allocate financial resources for transportation projects. However, cost analysis methods are not generally used for infrastructure investments, especially in developing countries like Brazil. This paper aims to present a method to support the identification, evaluation and prioritization of Railway projects that may contribute to address currently observed problems. The research applies a cost analysis technique, which was found suitable to analyze projects, without a need for expensive data collection neither complex models to produce satisfactory results. The method proved to be simple and efficient in meeting planning needs and helping the decision making.

Keywords: railways, developing countries, cost analysis, investments.

INTRODUCTION

Brazil's transportation matrix is essentially based on road transport, 96% of all the passengers use roads to move and 60% of the freight is carried on highways. This mode split has a very high cost to Brazil, because the railways have a lot of advantages when compared to road transport, especially for long distances. Brazil is a very large country (8,500,000 km² of area) and exports many commodities, such as coffee, soybeans and iron ore. Freitas et al. (2004) and Rodrigues (2004) highlight other advantages for railroads in Brazil, as inland agriculture production, particularly efficient for massive volumes and bulk transportation and it is safer than trucks (in terms of accidents and assailment risk). Thus, transportation by rails requires less cost, less energy consumption and so has a lesser impact on the environment and it is safer than roads.

However, railroads in Brazil have a lot of needs. Brazil invests only 0.06% of the Gross Domestic Product in infrastructure when the BNDES – National Bank of Development recommends that 2.5% of the GDP should be invested in infrastructure. According to Vilaça (2005) Brazil wastes in average US$ 1 billion because of the lack of appropriate transportation system. Also, a national survey conducted in 2004 shows that the country needs to transfer 40 million tons from the highways because the roading infrastructure does not support anymore the load. Thus, there is a need to make investments to seek the reduction of these costs and promote the national development, in a way that government resources are employed effectively and efficiently to solve the current problems.

Public and private initiatives invest every year millions of dollars in infrastructure projects. However there is no strategic plan to indicate how and where to allocate public resources. Also no technique is employed to show what the priority investments are. This issue makes industry and government to spend the limited available resources frivolously and unwisely. Thus, a methodology as the economic analysis of projects is imperative to identify, evaluate and prioritize investments, helping on the decision making on what projects to invest and to justify to society the choice, based on its costs and benefits.

This paper is divided into five sections. After this introduction, the next section shows the history of railways in Brazil as well as the current situation, exposing the reader to the context of the Brazilian rail system and the problems that need to be addressed. The third section is the economic analysis of projects where the techniques are investigated to determine the best method to be applied on railway projects in a developing country. The following section is the case study, where the application of cost analysis is made for the Brazilian reality and also the results are presented. This paper is enclosed with the final conclusions and recommendations for future work.

RAILWAYS IN BRAZIL

The first locomotive in World history was built in 1804 by Richard Trevithick. The first operational locomotive, a traveling engine designed for hauling coal on the Killingworth wagon-way, was built in 1814 by the English mechanical engineer George Stephenson; it was called Blucher. In Brazil, the first railway had only 14 kilometers and it was built in 1854.

At that time, the Imperial Government implemented a policy to stimulate railways construction, giving several benefits for national and international companies. This policy has brought a lot of consequences to the system that remains today. That is why the Brazilian railways are spread, have long and winding tracks, very high grades and three kinds of gauge sizes: the standard with 1,43m (sometimes called “Stephenson gauge”), the broad with 1,6m and the narrow gauge with 1m. These problems happened because each company constructed a railway according to their needs and wishes, without an integration idea.

Despite such initial disarray, the Brazilian railways continued to grow up and around 1910 they started a period of huge development. Some electrified locomotives were implemented at that time, but because of the high costs of maintenance they were substituted for the diesel technology in 1943. Concomitantly it was observed the peak on railway development in Brazil, in terms of size, technology and policy.

However, by 1957, the system already had a lot of problems such as low speeds, low profitability tracks and weak power locomotives. Thus, the Government decided to nationalize the system and create the RFFSA – Brazilian Federal Railways Company. However, the national transport strategy was to invest on roads and other transportation modes. Consequently, the rails were neglected to a secondary role in Brazil's transport system added to the coffee crisis (extremely connected with the railway growth) and fragile moment for the railways finances (Oliveira, 1978).

In late 1980's the RFFSA was not profitable enough to pay the bills and the government was without credit to keep financing the system. So, in 1992 the RFFSA has been included in the National Program of Denationalizations. In 1996 the denationalization process was initiated and finished at 1999. The allotment analysis resulted in a model based on geographic division, derived from the regional administrative branches (Oliveira, 2005). This model is criticized for making difficult the intermodality and requiring a strong regulation from the government, and a model based on corridors is appointed as more operational.

The Current Situation

The Figure 1 shows the map of the Brazil's railway system, as it is nowadays. There are 12 concessions distributed in 28.476 kilometers. The dashed lines on the map are future projects. The thin lines represent the metric gauge and wide lines the broad gauge. Note that the railways are more concentrated in south and southeast regions of the country.

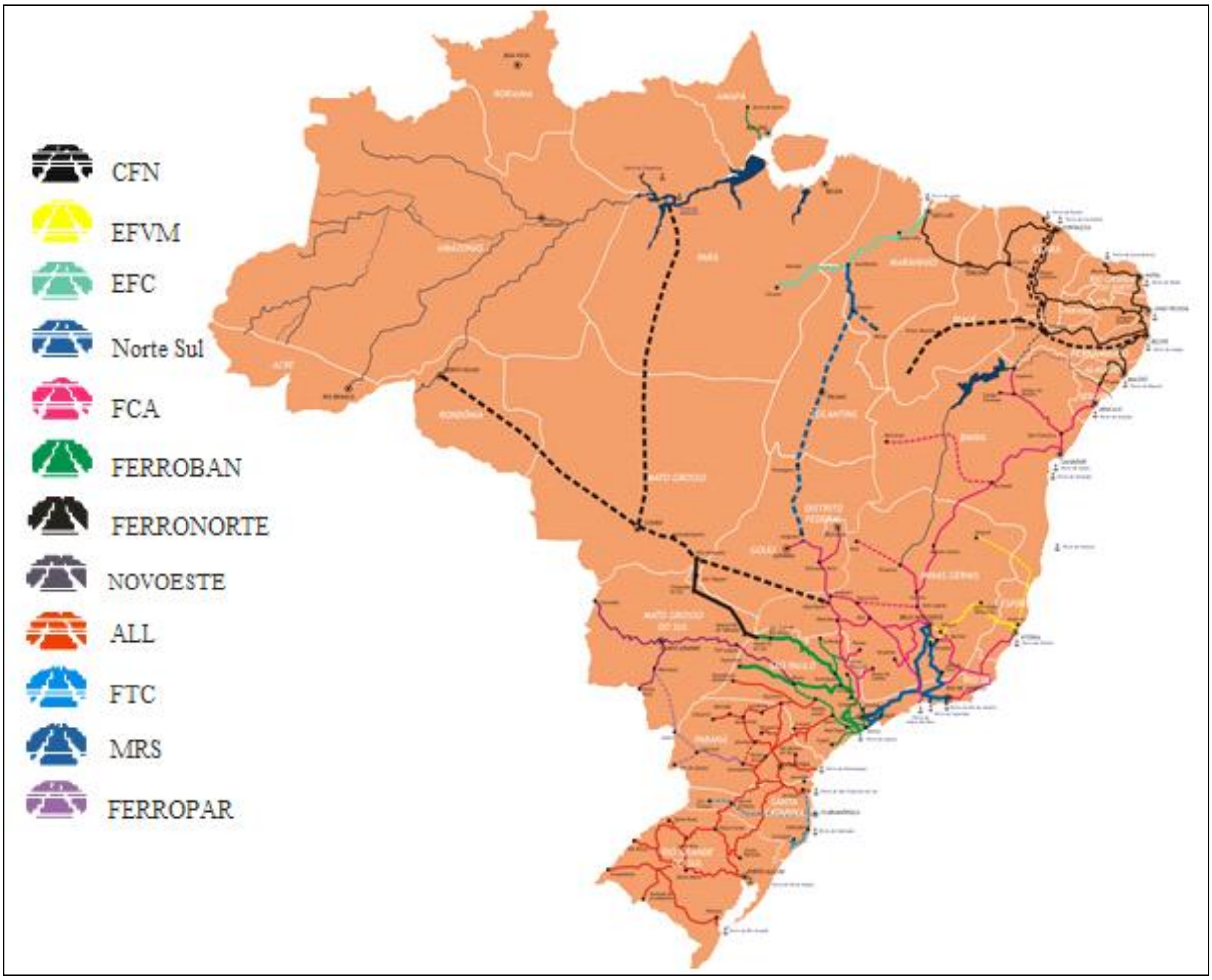

Figure 1 - Map of the Brazilian Railway System
Source: ANTF (2006)

It is important to emphasize that Brazil's denationalization process occurred in different forms. For the majority of the companies the process occurred through concessions. The concessionaires lease tracks, rails, locomotives etc. and after 30 years of investments they have to return it to the government. The selling process was made in auctions. Each regional branch from the RFFSA was created as a new concessionaire.

The process was relatively fast; in less than 3 years the entire railroad network was transferred to the private sector; in some countries this process took eleven years (Kraemer, 2002). Another particularity of the Brazilian case is that the decision was to sell by auctions the network as it was, without previous investments or maintenance. This decision was taken after the observation of the USA and New Zealand experiences. In the USA the government spent, between 1976 and 1985, US$ 10.3 billion to recuperate their rail network, receiving only US$ 1.6 billion with it sells and in New Zealand the government received four and a half times less than they had invested in improvements (Panorama Setorial, 2001).

The introduction of private capital after 1996 had increased the investments. In 1997 there were 560 million Reais in investments and in 2006 there were more than 2 billion Reais. The current problem is that Government assumes that once the concessionaires are investing there is no need to also endow public money. However the concessionaires have to return the railroads to the government when the contract expires, after many long term investments. Furthermore, the concession contracts state that the railways are public property and the government is responsible to provide basic infrastructure and to make the expansions. Notably, the major problems in the rail network already existed before the denationalization process.

The outcomes of the private investments can be observed in an 81% reduction in accidents between 1997 and 2006, the volume transported has increased by 60%, many jobs have been created (almost duplicated), and levying and the operational productivity have improved (ANTF, 2007). An example of the revival of the rail industry is the national production of freight cars, which in 1996 were 26 units and in 2006 were 3589 wagons (ABIFER).

Even with the significant increases, there are still many problems, mostly in urban areas. The main problems are:

1. Illegal Occupation of Right-of-way Strips, especially in port accesses. Right-of-way strips were illegally occupied, from obstructions to entire cities, which forces the trains to reduce speed, becoming vulnerable to attacks. Therefore, these occupations increase the risk of thief and also of deaths, associated to the threat of living near the tracks. Hence, the government must intervene to remove this population or build variants or contours. The Figure 2, on the left hand side, illustrates an example of invasion of the right-of-way strip on the access of the port of Rio de Janeiro.

2. Critical Level Crossings. The lack of signalization is critical in some points and there is generally a lack of information for the population. In those level crossings trains have to brake and almost stop suddenly, which is not an easy operation for trains with many wagons. It was estimated in 2005 that there are about 12,400 level crossings in the rail network; which 1,200 were considered critical and 134 of urgent intervention. These crossings have an enormous risk of accident because of the amount of people and vehicles or because of the deficiency on the signals. The right hand side of Figure 2 shows one critical level crossing in Betim, Minas Gerais.

3. Logistical Bottlenecks, generating conflict between railway, cars and pedestrian traffic. These bottlenecks are normally in urban areas and some are simultaneously with critical level crossings and illegal occupation of the right-of-way strips. The eliminations of these bottlenecks have a massive positive impact for the communities living close to the tracks, reducing the risk of accidents and also for the economy, increasing the flow of trains and raising the operational performance.

4. Legal and Regulation Barriers, can also negatively impact on the system. There is an urgent need to produce rules and laws, stimulating and enhancing private investments (ANTF, 2006). The legal and regulation barriers embrace, among other obstacles, harmonizing the current norms to the reality of the railway operations, creating goals to improve security and productivity, which is still the government's task, simplify payments and inspections to the network.

5. High Import Taxes. Brazil has a tariff policy to impose high taxes to imported goods, protecting the internal market. The high import taxes are particularly negative to the

railways, as many of the essential equipments have to be imported, since they are not produced internally. Thus, it is foremost to the rail companies to reduce import taxes of products that have unavoidably to be imported, such as steel rails and locomotives.

6. Expansion of the railway network integrating countries and the transport infrastructure, as the New Transnordestina (construction of 880 km and remodeling of 1,180 km), the Construction of Alto Araguaia–Rondonópolis section (236km) and others (Lang, 2007).

Figure 2 - Example of an Invasion of the Right-of-way and a Critical Level Crossing

Source: ANTF (2006)

ECONOMIC ANALYSIS OF PROJECTS

Taking into consideration the characteristics of the railways in Brazil, presented in the previous section, many investments are necessary to address the existing operational and administrational problems. The concessionaires did in 2005 a list that summarizes the 23 more urgent projects for the elimination of physical and operational bottlenecks, demonstrated on Table 1, with an estimated cost made in 2006. Of course, these projects are important to increase the productivity of the railways. In one hand they will give more profit to the concessionaires, on the other hand they will help the development of the economy and increase the wellbeing of the population surrounded by these projects.

Table 1 - Major railway projects.

Railway Projects	Estimated Value	
	Million BRL	Million USD
Segregation of freight track within the São Paulo Metropolitan Area	150	83
Removal of illegal occupants from right-of-way strips in major cities	81	45
Barra Mansa Crossing, Rio de Janeiro	32	18
São Paulo Ring Railway – North Section (PPP)	850	472
Serra do Tigre Variant, between Ibiá and Sete Lagoas	1,498	832
São Félix Railway Contour – Cachoeira, Bahia	110	61
Vila Velha Contour	99	55
Camaçari – Aratu Variant, Bahia	140	78
Guarapuava – Ipiranga Bypass, Paraná (PPP)	450	250
Curitiba Railway Contour, Paraná	150	83
Jaraguá do Sul, Joinville and São Francisco do Sul Railway Contours	150	83
Serra do Mar Duplication (Curitiba – Paranaguá Variant, Paraná)	450	250
Port of Santos Access	20	11
Signaling at municipal level crossings	20	11
Removal of illegal occupants from right-of-way strip	20	11
Implementation of the Campo Grande Logistical Complex, by the new Contour	50	28
Amplification of the Siderópolis Line (12 km)	8	4
Bridge / screen at Criciúma, Santa Catarina	18	10
Solution of interferences on the urban perimeters (Level Crossings)	115	64
Access to Maritime Terminal of Ignácio Barbosa/SE	80	44
Contour of Aracaju	50	28
Belo Horizonte Crossing	137	76
Araraquara/SP Crossing	36	20
Grand Total	***4,714***	***2,619***

Source: ANTF (2006) and Exchange Rate (2010).

All the projects mentioned on Table 1 require public investments and some of them are expected to happen as PPP (Public and Private Partnership), but the Government does not have a methodology to identify the correct needs and prioritize these projects. At the moment, investments are solely made on the bases of political influence and lobby from rail companies. In this context this research aims to help the decision making process.

In order to choose the best method to prioritize railway investments, many techniques were studied as well as broad conceptual and methodological principles from the economic analysis of projects. It was observed that the methodology that better adapt to railway projects are the cost analysis evaluations for its applicability on several areas of public interest, including education, health, transportations and other fields. Multicriterial analysis was also contemplated due to its popularity in Brazil. Nonetheless, multicriterial analysis was revealed as a data intensive technique and it is hard to establish goals and select preferences among the alternatives.

The public sector should be always concerned in identifying ways to use existing resources more efficiently and the decision making must be based on which investments will produce the greatest return to society. Policy decisions in the public sector have to be based increasingly upon a demonstrated consideration of both the costs and the effects of such decisions, as well as other aspects of the alternatives (Levin and McEwan, 2001).

The purpose of cost analysis is to provide a method for choosing among alternatives in order to select those that are able to accomplish a given result most prudently. The concern in the public sector should be to obtain the best results for the resources spent, instead of relying upon guesswork or politics to make these hard decisions (Levin and McEwan, 2001). According to the same authors, cost analyses makes it possible to choose the alternatives that provide best results for any given resource or that minimize the resource utilization for any give outcome.

Cost analysis evaluation refers to the use of a broad set of techniques for evaluation and decision making, including cost-effectiveness, cost-benefit, cost-utility and cost-feasibility. Each type of analysis is on the group of cost analysis techniques and has important differences that make each one appropriate to specific applications (Levin, 1975). The methods are intended to compare the costs of alternative with its outcome and then help on the decision making for the best interventions.

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is the technique that evaluates alternatives according to its costs and benefits. For each alternative of investment the costs and the benefits are calculated in monetary terms. The alternatives are compared and the choice is for the one that has the highest benefit-cost ratio or, alternatively, the lowest ratio of costs to benefits.

CBA is probably the most used technique to cost analyse projects and it has many advantages. One of the advantages is that it considers all alternatives in terms of the monetary values of costs and benefits, allowing comparing various projects with many different objectives, as long as their costs and benefits can be expressed in pecuniary terms. Also, using a cost-benefit method it is possible to compare between programs from different fields (e.g., transportation with environmental improvement and health) competing for public resources.

Costs and benefits occur at different time periods and they need to be set on a comparable basis. They should be presented in real values of the evaluation year, converted then to present values. The present value is determined by discounting expected future net returns, during its economic life, at a rate which reflects opportunity costs and/or time preferences. The recommended procedure is first to make the best average estimates of each cost and benefit and to forecast the average net social benefit or net present value that is likely to occur given the range of risks and uncertainties (EDANZ, 2007).

The present values of costs and benefits are added up and compared. The result will serve as a parameter to choose an alternative or to its further evaluation. The objective is maximizing the present value. Any alternative should be implemented if its costs exceed its benefits. The decision is based on the alternative that has the highest ratio of benefits to costs as an overall, independent of its field.

Other advantage of CBA include that it makes explicit the economic assumptions that might otherwise remain implicit or overlooked at the design stage. The level of detail of the assumptions depends on the degree of sophistication of the applied approach, and even CBA can be rather vague. Specifying the assumptions is useful for convincing policy-makers and founders that the benefits justify the investment; and it is a good quality approach for estimating the efficiency of programs and projects.

On the disadvantage side it comprises the likely unavailability of the data for the cost-benefit calculations and projected results may be highly dependent on assumptions made; the results must be interpreted with care, particularly in projects where benefits are difficult to quantify; and the method requires adequate financial and human resources to its assessment, due to be quite technical (EDANZ, 2007). Other disadvantage of this method is that benefits and costs must be assessed in monetary terms, which is not often possible to do in a systematic and rigorous manner. For example, it is difficult to assess some benefits such as improvements in self-esteem, people wellbeing and quality of life. Another important disadvantage of this method is that results can be easily manipulated. Flyvbjerg *et al.* (2002) has compared the expected results of CBA with the gained benefits of projects, on project ex post analyses and observed overwhelming underestimations and misrepresentations. The authors made severe critics to the method and concluded that cost estimates and cost-benefit analyses produced by project promoters and their analyst should never be trusted.

These shortcomings suggest that only under certain circumstances the cost-benefit analysis should be used (Levin and McEwan, 2001). Those circumstances happen when the preponderance of benefits can be easily converted to monetary values or when those that cannot be converted can be ignored or can be shown to be similar among the alternatives that are being considered. However, in those cases in which the major benefits are difficult to assess in pecuniary terms, some other mechanism for assessment must be found. On one hand, methods to convert intangible benefits into monetary values have been thoroughly studied. On the other hand, there are still gaps to be filled, as some intangible benefits have yet to be assessed. At the same time, the difficulty of the technique only increases in developing countries, where the available literature would have to be transferred to the local context and a large amount of data would have to be collected. Both cost-effectiveness and cost-utility analyses represent analytical frameworks that do not depend on the ability to represent benefits in pecuniary terms (Levin and McEwan, 2001).

Cost-Effectiveness Analysis

Cost-effectiveness analysis (CEA) refers to the evaluation of alternatives according to both costs and effects with regards to producing some outcome or set of outcomes (Levin, 1983). CEA must focus on the choice of one intervention or alternative for meeting a particular objective. The CEA assumes that the choice between alternatives is in the conjecture that the resources are limited (Silva, 2003).

Costs are combined with measures of effectiveness and all alternatives can be evaluated according to their costs and their contribution in meeting the same effectiveness criterion, these are ingredients for a CEA (Levin and McEwan, 2001). CEA is popular in health and educational evaluation and decision making. The reason for this is that effects are normally dependent on one parameter as increasing test scores in basic skills, reducing the number of students who drop out, number of lives saved and number of life-years increased.

From a decision oriented perspective, the most preferable alternative would be those that have the lowest cost for any given increase in the effect, or alternatively highest effect for any given cost. By choosing the most cost-effective alternative, we make resources available to be invested in other projects. It is assumed that (a) only programs with similar or identical goals can be compared and (b) common measure of effectiveness can be used to assess them (Levin and McEwan, 2001). These effectiveness data can be combined with costs in order to provide a cost-effectiveness evaluation that will enable the selection of those alternatives that give the greatest effectiveness per level of cost or that require the least cost per level of effectiveness.

The cost-effectiveness analysis has various strengths. It does not require a lot of data to its application; it just combines cost data with the effectiveness data that are usually available. It is easy to understand, since alternatives are being evaluated by how much they achieve a particular goal. The most important advantage of CEA is that it is not necessary to convert intangible benefits. Also the technique can be employed to evaluate different infra-structure projects that take account of the same problem.

Conversely, CEA has some weaknesses. One major disadvantage of CEA is that alternatives can only be compared if they have similar objectives. It is not possible to compare alternatives with different goals or to make an overall determination of whether a program is worthwhile in an absolute sense (Levin and McEwan, 2001). That is, we can state whether a given alternative is relatively more cost-effective than other alternatives, but we cannot state whether its total benefits exceed its total costs. That can only be ascertained through a cost-benefit analysis.

Cost-effectiveness analysis provides a quantitative framework for evaluating the complex and often conflicting factors involved in the evaluation of programs. It helps ensure that all costs and effects resulting from an intervention have been properly evaluated. The application of cost-effectiveness studies had increased as a result of rising investment costs and the desire to achieve the best results possible.

Cost-Utility Analysis

Cost-utility analysis (CUA) is similar with CEA. It refers to the evaluation of alternatives according to a comparison of their costs and their utility or value. “Utility” is a term frequently employed by economists to express the satisfaction derived by individuals from one or more outcomes (Levin, 1983). Unlike CE analysis, which relies upon a single measure of effectiveness CU analysis uses information on the preferences of individuals in order to express their over-all satisfaction with a single measure or multiple measures of effectiveness at a time (Levin and McEwan, 2001).

Data on individual preferences can be derived in many ways, either through highly subjective estimates by the researcher or through more rigorous methods designed to carefully elicit the opinions of individuals. Once overall measures of utility have been obtained, the procedure is almost the same as in CEA. We choose the interventions that provide a given level of utility at the lowest cost or those which provide the greatest amount of utility for a given cost.

CU analysis is often used to combine multiple measures of effectiveness into a single estimate of utility. One transportation project has effects in many areas as reducing the number of accidents, injuries and deaths; raising the productivity; increased peace in the surrounding community and so on. It would be convenient to produce an overall measure of utility of a given intervention, which encompasses information on all the measures of effectiveness. One method of doing so is to weight each measure of effectiveness by an "importance weight". The weights should reflect the contribution of each measure of effectiveness to the overall utility of the decision maker. Weighted estimates can then be summed in an overall utility measure, for example, decision makers (or another group of individuals) may feel that one kind of achievement is relatively more important than another.

The advantages of the CUA are that the data requirements are less strict, a large number of potential outcomes can be included in the evaluation, and imperfect information and uncertainty can be addressed systematically. The major disadvantage is the fact that the results cannot be reproduced on the basis of a standard methodology among different evaluators, since most of the assessments are highly subjective ones that take place in the head of the person doing the evaluation (Levin, 1983). There is a high probability that other evaluator with the same information and methodology may obtain a totally different result by using a different set of probabilities of outcomes and the values of those outcomes. So, there are many problems in taking the utility assessments of individuals and aggregating them to obtain a "social utility" approach (Arrow, 1963).

Cost-Feasibility Analysis

CBA, CEA and CUA all have similarities. They all enable a choice among alternatives by obtaining some measure of both costs and results for each potential strategy, so that one can choose the approach that has the lowest cost for any particular result or the best results for any particular cost. However, there is one situation in which estimates of costs alone are important and on these cases we should use cost-feasibility analysis (CFA).

CFA refers to the method of estimating only the costs of an alternative in order to ascertain whether or not it can be considered (Levin, 1983). That is, if the cost of any alternative exceeds the budget and other resources that are available, there is no point in doing any further analysis. If there is a fixed amount of money available, then any alternative that violates this constraint would not be feasible. Cost-feasibility represents a limited form of analysis that can determine only whether or not alternatives are within the boundaries of consideration. It cannot be used to determine which ones should actually be selected.

The Chosen Method

It was necessary to select the most suitable method for assessing railway projects after observing the characteristics of each cost analysis method studied. It was also essential to observe what the data available was and how to process it. Firstly we had to identify the most important benefits of railway projects. They were broken down in economic benefits and social benefits. The economic benefits are increase of national transport productivity, the average speed of trains and the tax collection, as well as reduction in the flow of trucks that leads to reduced congestion, environmental problems and overloading of the roading network. The social benefits are the reduction of accidents, the attenuation of the interferences with local communities and generation of jobs, especially during constructions.

Cost Benefit Analysis could not be used since it was hard to convert the intangible benefits in monetary terms as reduction of accidents and attenuation of the interferences with local communities in a Brazilian context. Cost-feasibility analysis, as stated above, cannot be used to determine what investment to choose. Both cost-utility and cost-effectiveness analysis seem to be applicable to railway projects. However, McNeeley (1991) and McNeeley *et al.* (1997) do not recommend using CUA in developing countries, because it would be complex to convert each attribute into a common utility scale that express the strength of preference for the attribute.

Cost-effectiveness analysis was employed because it includes well the social benefits of a project and does not require an exhausting data collection, nor complex models. CEA is well established for the choice of the variables, and consequently it has less subjectivity than other methods. Levin (1983) highlights that some evaluators often consider only the effects or only the costs of an alternative, in both cases the evaluation is incomplete. Both costs and benefits must be considered and integrated to make good decisions in public endeavors.

It is subject to a constant barrage of criticism that it does not operate in a “cost-effective” or “efficient” manner. Yet widely cited by politicians, administrators and evaluators, cost-effectiveness analysis is not well used in practice. One of the reasons is that few evaluators have received training to use cost-analysis methods. In Brazil this is even more evident. CEA is almost inexistent, few studies that utilize CEA were found and they were focused on health and environment analysis. In other countries it is more popular; however for infrastructure projects the technique is still superficial and not very clear.

CASE STUDY

The cost-effectiveness analysis was then adapted to railway projects. Initially we had to define the steps to precede the cost analysis, as shown in Figure 4.

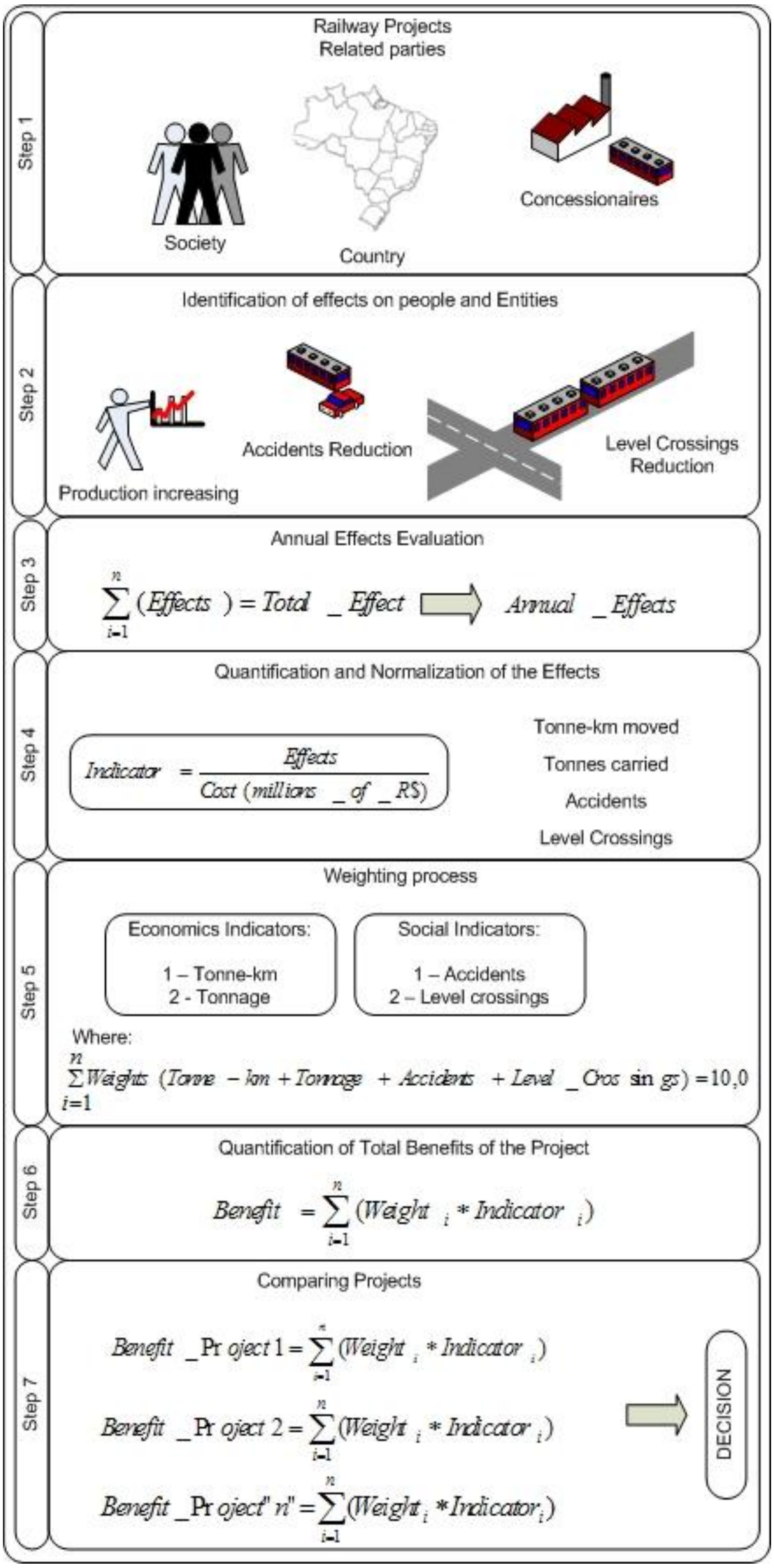

Figure 4 - Steps to do the Cost Effectiveness Analysis

Initially there was a huge effort to obtain data for the analysis. The data obtained was the most important constraint to define what kind of cost analysis to do and how. As observed in Figure 4, the first step was the identification of involved parties as society, country and concessionaires. The next step was focused on estimating the effects on people and entities. These effects should be evaluated in measurable terms and we had to define which benefits would be considered. The chosen benefits were production increase in ton-km moved and tonnage, the accidents reduction and level crossing reduction. Level crossing reduction not only has the potential to reduce accidents, but it increases train speed and reduces the interference with the rest of the transport network and public in general, increasing quality of life to the communities surrounding the railways and increased performance to the railways. In step 3, annual effects are evaluated. Step 4 comprised the quantification and normalization of the effects, dividing the effects per cost.

The subsequent step was a weighting process. The indicators were selected, based on their availability and importance. The economic indicators chosen were: Ton-km moved and tons carried; and the social indicators were: accidents and level crossing reductions, even though level crossing reduction also has an economic aspect, they were considered indirect effects. To identify how much each indicator contributes to the total benefit a weight was assigned to each one of them. After that, the net effect off all the parameters was considered by multiplying each weight per indicator and adding them up. Next, the total benefit for each project was calculated and according to this value, the projects were compared.

The National Association of Railway Transporters (ANTF) provided the database used for the case study with ten projects to be analyzed. Unfortunately, due to a commercial sensitivity issues, the projects can not be identified. The requested anonymity of the project has forced us to call the projects A, B, C, D, E, F, G, H, I and J. The ANTF provided the costs for each one of the ten projects, as well as the overall effect of each parameter, as shown in Table 2. To maintain the confidentiality, the estimated value of the project had to be omitted.

Table 2 – Projects' details used for the CEA.

Project	Kind of Project	Increased Volume (Million Tonnes)	Increased Production (Billion Ton-km)	Reduced Accidents (accidents/ year)	Reduced Level Crossings (number)
A	Level Crossing and right-of-way strip	-	-	-	4
B	Contour	5.51	2.16	140	20
C	Contour	5.95	2.33	50	27
D	Contour	1.91	1.32	47	63
E	Contour	-	-	67	146
F	Contour	-	0.22	30	21
G	Level Crossing and right-of-way strip	-	-	3	3
H	Variant	11.47	7.91	-	
I	Variant	1.44	0.99	-	
J	Level Crossing and right-of-way strip	1.10	0.08	6	6

A sensitivity analysis was conducted with 8 criteria, as shown in Table 3. The indicator received a different weight for each criterion. The reason for the sensitivity analysis is to show different results for the same data set. The definition of criteria should be made for the evaluator and the decision would probably be different depending in what is the purpose of the evaluator. For example public and private initiatives would probably have different weights for the criteria.

Table 3 - Weights of each criteria considered on the sensitivity analysis.

Criteria	Weight of the Tonnage	Weight of the Ton-km	Weight of the Accidents	Weight of the Level Crossing
1	0.0	0	0.6	0.4
2	0.1	0.2	0.5	0.2
3	0.0	0.35	0.35	0.3
4	0.2	0.3	0.3	0.2
5	0.25	0.35	0.25	0.15
6	0.2	0.5	0.2	0.1
7	0.4	0.6	0.0	0.0
8	0.0	1.0	0.0	0.0

In first criteria we are only interested in the social benefits. Therefore, economic benefits were not directly considered. Weight 6 was attributed to accidents and weight 4 was assigned to level crossings. In the second criteria, a small weight was given to economic benefit, but still social benefit had high weights. In our analysis, accidents are considered more “important” than level crossing because they cause more damage to the communities and also to society, as well as their benefits are more precisely indicated. The ton-km moved has a higher weight than tonnage because it gives a best profit return in terms of economic benefit. In the next criterion more weight was given to economic benefits. Finally in the last two criteria the social indicators were not considered.

For each criterion we run the analysis and they gave relatively different results, as observed in Table 4. Considering the first criterion, project E had the highest priority. The second highest ranked was project C and so on. In the criterion 2, the same occurred and the highest priority is project E, follow by C and so on. Analyzing the first six criteria sets, there is no considerable differences in terms of priority projects. On the other hand, criteria 7 and 8 present significant differences because only economical benefits were considered.

Table 4 - Prioritization results for each criterion

Priority	Criteria 1 Projects	Criteria 2 Projects	Criteria 3 Projects	Criteria 4 Projects	Criteria 5 Projects	Criteria 6 Projects	Criteria 7 Projects	Criteria 8 Projects
1	E	E	E	E	E	E	C	C
2	C	C	C	C	C	C	J	H
3	D	D	D	D	J	J	H	D
4	J	J	J	J	D	D	D	J
5	F	F	F	F	F	F	I	I
6	G	G	G	G	G	G	B	F
7	B	B	B	B	B	B	F	B
8	A	A	A	H	H	H	A	A
9	H	H	H	A	A	A	E	E
10	I	I	I	I	I	I	G	G

The project E had the highest priority in the six first criteria sets and becomes one of the lowest ranked projects in criteria 7 and 8. This occurred because project E would generate many social benefits but no economic benefits were measured. In contrast, project C had the second highest priority in the criteria sets 1 to 6. But, in criteria sets 7 and 8 it becomes the highest ranked project. The reason for this is that project C would generate many social benefits as well as economic benefits. On the other side of the spectrum, project A had low priority in the rank for all criteria sets. This is because project A would not generate many social nor economical benefits. Due to the fact that for a few criteria set the results are exactly the same, we could have disregarded a few of criteria. However, this finding should not be generalized to all applications of the method.

It would be said that if the Government was interested in invests in of these projects, probably it should choose project E. However, it is very likely that the Government would not have enough financial resources to implement project E. But, it would have the resources to implement project D. Therefore, the selection of the project would actually depend on the resource availability. For this reason a cost-feasibility analysis is important, especially in developing countries. The availability of resources is limited and a CFA would help to overlook projects that cannot fit on the budget.

However, there is the option of having an agreement between the public and private sector to invest on project C, for instance. It is a usual situation in which government does not have all the resources to endow one project and frequently private initiative has interest in investing and would be pleased to do a partnership with the public sector.

Finally, it should be recommended that various combinations of weights and criteria should be tested in order to give comprehensive knowledge about the problem and the decisions. However if the evaluators know what is the focus of the analysis they could take in consideration only one criterion or better define the weights. There is for example a program to stimulate the reduction of level crossings. In this case probably only this criterion should be taken in consideration. Therefore, the CEA does not generate the final result, but it is a tool to help the decision making.

CONCLUSIONS

On one hand, there is a scarcity of public capital to invest on transportation projects in developing countries. On the other hand, the available resources are not well allocated, with little or no prioritization. Thus, the use of techniques for the economic analysis of projects, defining both social and economic benefits, is essential to assist the decision making process. This may seem evident, but in Brazil cost analysis methods are not generally used for infrastructure investments. There is a “myth” in the country (and in other developing countries) that there is no time and resources to do an economic analysis of projects before the decision making and because of this sometimes investments are imprudently made.

This paper investigates different methods to choose the most appropriate to identify, evaluate and prioritize investments considering the Brazilian railways’ characteristics. The investigated methods were Cost-Benefit Analysis, Cost-Effectiveness Analysis, Cost-Utility Analysis, Cost-Feasibility Analysis and Multicriteria methods. The selection process reflected on factors such as data collection and availability, transparency of the process, type of results and quality of the outcomes, considering the characteristics of a developing country (Brazil) and the needs of this kind of projects. It was concluded that the method that better suits this study was the Cost-Effectiveness Analysis (CEA).

This endeavor was probably the first experience of an application of cost-effectiveness analysis for infrastructure projects in Brazil. The CEA does not involve expensive data collection neither complex equations and models to produce satisfactory results and is also suitable to evaluate social benefits of projects. The technique has proved to be easy and the applicability can be simple, coming to break the myth of complexity and time consuming of cost analyses. The application of cost analysis methods give consistency to public decisions and help on the justification of them, making them less ambiguous. Otherwise, the bureaucrats can deliberate according to their own interests and not with the public needs. Thus, methodologies with clear rules give more confidence to the choices made. Especially in Brazil where there is instability on infrastructure policies, results and actions different from expected outcomes are suppressed and society is regularly questioning government decisions.

From a list of priority projects, ten were selected to serve as a case study. For each project it was necessary to identify the total cost of the project, the generated increase of production, in terms of ton-km moved, tonnage, accidents reduction and reduction of interference with local communities. A sensitivity analysis was conducted with different weights for each of these parameters. It was observed that even with extreme variation of weights in the sensitivity analysis the results did not show significant differences. The three projects that had highest benefits were related to railway contours. If the projects were to be financed only with public capital it is expected that the analysis would take an approach of giving more weight to social benefits than to economic ones, different from projects finances also (or only) by the private sector.

We tried to investigate the problem and the methodology as much as possible. The employment of cost-effectiveness analysis for ten priority railway projects has a social side. The sensitivity analyses enhanced this study showing that there is not a single solution or way to evaluate projects. It comes to verify if a change in the importance of the indicators modifies the final evaluation of one project. It however opens it to the subjectivity and to reduce this, the evaluator should establish its choice on technical parameters.

The structure of this paper shows concepts from the Brazilian reality of the railways and policy. The case study illustrates an application of cost-effectiveness analysis as a feasible and adaptable technique, but does not aim to exhaust all its potentialities. It has however, several different restrictions that were arisen during the research, as the quality of database. The data collection should be carefully done to avoid inaccuracy. Errors can have an enormous impact on the results and then end in a wrong decision (Correia, 2004). Though, the data used for the case study was provided and we do not know what was the methodology used to compile the information. Other critic point is the lack of the validation of results with specialists of the area after the analysis to corroborate with the conclusions.

A contribution is the exploitation of economic analysis of projects from engineers. This kind of analysis is more frequently made by economists. Of course, they have more experience and the wording found in the literature is quite technical. However it can be used for different areas of knowledge, since it is multidisciplinary. The research attempted to stimulate different professionals to explore cost analysis methods showing the outcomes from a case study.

It is also recommended that for future projects the data collection be made more cautiously. Also it is suggested that other methodologies for the economic analysis of projects be applied. Another interesting analysis would be the incorporation of environmental impacts of the above projects, which was not made due the lack of available data, as well as include energy problems. It has been widely argued that railways are most cost efficient and it would be interesting to test this presumption with quantitative analysis.

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