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Ernane Rosa Martins
(ORGANIZADOR)

Ciência, tecnologia e inovação:

Fatores de progresso e de desenvolvimento

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APRESENTAÇÃO

A nossa sociedade está em constante evolução, visivelmente percebida no Brasil e no mundo, generalizada em todas as áreas do conhecimento. Esta obra pretende elucidar o panorama atual das organizações relacionando-as com a ciência, a tecnologia e a inovação, apresentando diversas análises sobre questões extremamente relevantes, por meio de seus capítulos.

Estes capítulos abordam aspectos importantes, tais como: os impactos causados pela implementação da BR-158 no cotidiano das comunidades indígenas no Estado do Mato Grosso; o quão a Profissão de Físico Médico é reconhecida ou desconhecida pela sociedade; os desafios enfrentados ao transformar o processo de Pré-Incubação para o formato virtual; a taxa de transferência padrão de oxigênio de um aerador comercial trifásico do tipo aspersão/chafariz 1,5 cv, através dos índices de SOTR (taxa padrão de transferência de oxigênio) e SAE (eficiência padrão do aerador); a análise da eficiência de websites de e-commerce a partir dos resultados de testes de usabilidade e dos dados que abrangem o desempenho dos mesmos na web; analise do Programa de Extensão “Reciclando o dia a dia - Promovendo a Cidadania”; quantificar os compostos Oxidativos e enzimáticos da Peroxidase - POD e Polifenoloxidase - PFO de 4 variedades de lúpulo (Chinook, Cascade, Columbus e EK Golding); analise dos motivos que levaram aos indeferimentos de depósitos de patentes em instituições de ensino, pesquisa e tecnologia no Brasil.

Nesse sentido, esta obra engloba uma coletânea de excelentes trabalhos de extrema relevância, por meio de experimentos e vivências de seus autores, socializando-os no meio acadêmico, proporcionando aos leitores a oportunidade de análises e discussões de textos científicos. Assim, desejamos a cada autor, nossos mais sinceros agradecimentos pela contribuição. E aos leitores, desejamos uma leitura proveitosa e repleta de excelentes reflexões.

Ernane Rosa Martins

SUMÁRIO

CAPÍTULO 12

ECONOMIC AND FINANCIAL FEASIBILITY OF THE MEXICO - TOLUCA PASSENGER TRAIN

Data de aceite: 01/10/2021

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ABSTRACT: In the 1990s, the railways needed to modernize its facilities and make more efficient their operations in an environment of scarce public budget, to remedy this situation the Mexican Government granted concession most of the country´s railways to support mainly cargo transportation at the expense of passenger transport that decreased significantly after granting process. Suburban trains in the metropolitan area of the Mexico City are planned to support the movement of passengers by rail at the beginning of this century, only is in operation since 2008 a 27 km stretch of the line one of the systems. Also, in the present administration is raised the construction with public resources of three lines of intercity passenger railway that only is in building process the México-Toluca train, 58 km long and medium speed. In this work is carried out the evaluation of economic and financial feasibility of the México-Toluca intercity train, whereas the construction difficulties, technological system, operation safety, costs and expected benefits.

KEYWORDS: Construction, railways, concessions, public works

VIABILIDADE ECONÔMICA E FINANCEIRA DO MÉXICO - TREM DE PASSAGEIROS EM TOLUCA

RESUMO: Na década de 1990, as ferrovias precisavam modernizar suas instalações e tornar mais eficientes suas operações em um ambiente de orçamento público escasso, para sanar esta situação que o Governo mexicano concedeu à concessão a maioria das ferrovias do país para apoiar principalmente o transporte de cargas em detrimento do transporte de passageiros que diminuiu significativamente após o processo de concessão. Trens suburbanos na região metropolitana da Cidade do México estão planejados para apoiar a circulação de passageiros por via férrea no início deste século, só está em operação desde 2008 um trecho de 27 km da linha um dos sistemas. Além disso, na atual administração é levantada a construção com recursos públicos de três linhas de ferrovia intermunicipal de passageiros que só estão em processo de construção do trem México-Toluca, de 58 km de extensão e média velocidade. Neste trabalho é realizada a avaliação da viabilidade econômica e financeira do trem intermunicipal México-Toluca, enquanto as dificuldades de construção, sistema tecnológico, segurança operacional, custos e benefícios esperados.

PALAVRAS - CHAVE: Construção, ferrovias, concessões, obras públicas.

INTRODUCTION

Railways are an efficient and economical means of transporting large volumes of passengers and cargo over a wide range of

distances, to the economic efficiency of railways increases as volumes or distance increase. The railways allow savings in cost, environment, energy, and land use more significantly than road transport, although in some cases rail transport is slower. The rail transport market is divided into two categories: passengers and freight. However, the business model of these two services is radically different even though in many countries freight and passenger railways use the same tracks, but the type of transport, equipment and details of infrastructure are often different (World Bank, 2011).

Passenger trains are a mode of passenger transport between and within cities, the typical segments of the passenger market in cities comprising metro, light rail, and tram transport systems, as well as suburban services, whereas passenger services between cities are usually regional and long-distance on conventional low-speed and medium-speed trains and modern high-speed trains.

Rail freight services are important for economic growth in many countries, as they transport large volumes of freight over long distances efficiently and at low cost. Freight trains usually carry bulk goods such as coal, mineral, grains, wood, and construction materials, as well as heavy industrial products, machinery, cars, and containers.

The railways had their time of growth and dominance as a means of transport for more than a hundred years, from the inauguration of the first passenger line in 1830 to the advent of mass use of automobiles and road transport, thereafter in most countries rail services passed into the control of governments, who had to bear the costs of investment, operation, and maintenance in an environment of low tariffs that forced the use of public subsidies.

In the 1980s a report (World Bank, 1982) stated that during the years following the Second World War the railways had become inefficient and obsolete public administrations, and therefore needed a profound structural change in which governments should: remove restrictions on competition in the railway's operation, limit subsidies, reduce staff, introduce new forms of management, and ensure that investments aimed at improving services to users.

A study (Huff and Thompson, 1990) defined the stages around which the restructuring effort of the railway company in the hands of the government should be organized: elaboration of a strategic plan linked to the political, social, and economic context of the country, design of an organizational structure as a commercial railway company and creation of a proposal for legislative, legal, and administrative changes. Another paper (Moyer and Thompson, 1992) raised issues related to the elimination of the state railway monopoly through the creation of operating companies paying for access to infrastructure managed by an independent company.

Thus, the European Commission initiated a long process to separate railway infrastructure from operations and required all operators to pay non-discriminatory access charges, the aim of which was to open the transport market to competition in freight and

passenger services in their different forms. Another aspect was the expansion of the private sector participation in rail services mainly in the American continent, in Canada in the form of privatization and in Argentina, Chile, Brazil, Mexico, Peru, Bolivia, Guatemala through concessions.

BACKGROUND

After more than two decades of construction, in January 1873 began to operate the first train in Mexican territory of 423 kilometers in length between Mexico City and Veracruz. Initially, the investments in the railway's construction were financed with private capital, primarily foreign, and through significant subsidies from the federal government (Medina, 2013).

By 1908, when National Railways of Mexico (NRM) was created, a state company that administers the concessions and operators of some railway lines, there was a railway network of about 20 thousand kilometers in the country, similar in extension to the current one and covering almost the entire national territory. The Mexican Revolution slowed the railroads development and caused a huge destruction of the heritage in infrastructure and equipment. In the following decades, it was necessary to rebuild the network and face the accumulated debt, forcing in 1937 the expropriation of the railroads operated by private companies.

Between 1940 and 1980 a long and important stage takes place. Mexican railways are modernizing and growing rapidly, in support of the country's industrialization model. However, during this period, the Mexican railroads have progressively deteriorated due to the use of subsidized tariffs for freight and passenger services, the increase in personnel, low productivity, and the government's poor administrative management of the company.

In the 1980s, the NRM crisis began, a huge debt accumulated, the financial deficit increased, and subsidies were permanent. On average, the NRM received a subsidy of $400 million per year during the 20 years prior to the concession (Andalón and López-Calva, 2003). At that time, various efforts were being made at the international level to improve the railways, to adapt them to the new needs of the market. Openness in the world economy required greater flexibility, efficiency, and quality in rail services.

In this context, between 1990 and 1994 the NRM structural change program was established with the aim of rationalizing the use of resources and outsourcing to the private sector, within the current legal framework, some activities related and complementary to the railway operation. These measures made it possible to substantially reduce the active personnel of the NRM, modify the collective agreement of the workers, carry out the maintenance of the tracks by contract, outsource the workshop service, eliminate the most unproductive services, and modernize the railway operations (Gorostiza, 2011).

Despite these measures, at the beginning of 1995 the need to continue improving the

efficiency of the Mexican railway system was highlighted, to make it the backbone of land freight transport in the country, so in March 1995 the decree was published that reformed the Constitution so that the railways ceased to be a monopolistic strategic area in the exclusive hands of the State and allow the private sector participation in this activity.

The public bidding process was opened in 1996 and concluded three years later with the granting of seven concessions for a term of 50 years for a total length of 17,010 kilometers for which the Mexican government received a payment of 2,343.3 million dollars. The Mexico Valley Terminal was divided equally between the three main concessionaires (KCSM, Ferromex and Ferrosur) and the federal government (Table 1).

Concessional route	Length (Km)	Concessionaire	Date	Pay (md)
Northeast Railway	4,283	KCSM	2-Dic-1996	1,457.0
Mexico Valley Terminal	297	Mexico Valley Railway	2-Dic-1996	0.0
Pacific Railway	8,107	Ferromex	22-Jun-1997	530.1
Coahuila-Durango Line	974	Coahuila-Durango Line	14-Nov-1997	22.7
Southeastern Railway	1,479	Ferrosur	29-Jun-1998	316.6
Chiapas-Mayab Railway	1,550	Chiapas-Mayab Company	26-Ago-1999	14.8
Nacozari Short Line	320	Ferromex	27-Ago-1999	2.1
Total	**17,010**			**2,343.3**

Table 1. Railroad concessions in Mexico

Source: Own elaboration with data from the Secretariat of Communications and Transport

The privatization processes gave rise to two different railway models: the American one, in which the vertically integrated sector was maintained where a company was given control of the infrastructure, the tracks and the operation of the trains; and the European one, in which horizontal separation was introduced that is based on competition between different operating companies over the infrastructure managed by an independent company.

In the case of Mexico, a variant of the American model of integration was used in the railroad concession. The distinctive element of the Mexican model is that of geographical origin competition. In this type of competition, although the concessionaires are monopolies on the routes that correspond to them, it is possible to pay fees of way to send goods to destinations other than those indicated in the concession.

The freight transport by rail under the NRM management had its climax in the year 1984, in which it mobilized 64 million tons: However, in the following decade it had a fall of 20.5% so that in 1990 it only transported 51 million tons. With the implementation of the structural change program, the movement of cargo was further improved, with the private sector receiving a partially healthy company during the concession process in 1996, since 59 million tons were transported in that year (Table 2).

Year	Freight transport (Millions)		Passenger transport (Millions)	
	Tons	Tons-km	Passengers	Passenger-km
1950	22.907	8,391	32.419	3,025
1960	34.358	14,004	32.587	4,128
1970	41.379	22,595	37.348	4,529
1980	60.592	41,330	23.680	5,295
1990	50.960	36,417	17.149	5,336
1996	58.831	41,723	6.727	1,799
2000	77.164	48,333	0.334	82
2010	104.564	78,770	0.213	64
2020	120.381	87,924	0.182	32

Table 2. Evolution of rail transport in Mexico 1950-2020

Source: Own elaboration with data from the Secretariat of Communications and Transport

Since the railways concession to the private sector, the movement of goods through this means of transport has been detonated; in twenty years of private administration, the tons of freight transported have doubled, as have the tons-kilometers transported by this means.

On the other hand, intercity passenger transport peaked in 1970, when more than 37 million passengers were carried. However, from that year onwards the movement of passengers by rail began to decrease significantly at an average annual rate of 6.8% in the period 1970-1996. With the concession, passenger transport between cities practically ended, only in the period 1996-2000 the number of passengers mobilized by rail was reduced by twenty times to go from 6.7 million passengers transported in 1996 to only 334 thousand passengers in 2000 (Table 2).

To achieve better passenger mobility by resuming rail transport, the Mexican authorities planned in 2012 the construction with public resources of three intercity passenger rail lines: the 58 km Mexico-Toluca train, the 336 km Trans peninsular train and the 210 km Mexico-Querétaro high-speed train.

The Mexico-Toluca train is under construction and is scheduled to start operations in late 2019, the Trans peninsular train was cancelled due to lack of public budget and the Mexico-Querétaro train was also cancelled due to budget cuts after being tendered and awarded for construction in 2015.

OBJECTIVE

The objective of this paper is to study the economic and financial feasibility of the 58 km long medium-speed train line between the cities of Mexico and Toluca with four intermediate stations. The costs of construction, maintenance, and operation, as well as the technical characteristics of the rolling stock have been compiled from the information

published by the Secretariat of Communications and Transport (SCT), as well as the project's potential demand for the three main sections into which the proposed tariff scheme is divided.

METHODOLOGY AND REFERENCE FRAMEWORK

Mexican government has established an institutional framework for the development of infrastructure investment projects whose purpose is to improve the quality of public investment through a more appropriate conceptualization and definition of projects, incorporation of risk analysis and determination of the best financing scheme. The main participants in the process are the ministry responsible for the sector, in this case the SCT that prepares the project's technical folder and the Secretariat of Finance and Public Credit that keeps the project's registration, control and approval.

The institutional framework consists of a main tool for developing investment projects called the Global Methodology of the Stages that Make Up the Investment Cycle (SHCP, 2012), which is applied following six stages: strategic planning, analysis and evaluation, prioritization, budgeting, monitoring and ex-post evaluation of investment projects.

In the "Analysis and evaluation" stage, the main costs and benefits are identified, quantified, and assessed to establish profitability from a socio-economic point of view. According to their amount, investment projects are categorized into three groups: small projects under $4.0 million need technical data sheet involving conceptual analysis, intermediate projects between 4 and 40 million dollars require simplified cost-benefit analysis, and large projects over $40 million require detailed cost-benefit analysis. The profitability indicators to define the advisability of carrying out the project are the net present value (NPV) and the internal rate of return (IRR) valued at a social rate of 10%.

SCT prepares the feasibility analysis of transport projects in four sections: technical, economic, legal, and environmental. The cost-benefit analysis of the projects is carried out by calculating the generalized travel costs (GVCs) for the situations with and without project, the benefits are obtained from the difference between the two situations, the evaluation is complemented considering the costs of construction, equipment, operation, and maintenance. The generalized travel costs are composed of the vehicle operation costs (VOC) and the travel time (TT) costs of users calculated over the project horizon (CEPEP, 2015).

Vehicular operation costs (VOC) were calculated with the Highway Development and Management (HDM4) model developed by the World Bank, considering the technical specifications of the vehicles circulating in Mexico, the pavement conditions, and the different orographic conditions (Arroyo and Aguerrebere, 2016). Vehicular operation cost considers the volume of daily vehicles of cars and buses that benefit from the entry into operation of the project according to the estimated demand for private and public transport. Savings in

travel times (TV) are calculated with the estimated demand for users from private (cars) and public (buses) transport based on the time social value (Arroyo et al, 2018).

The financial feasibility of the Mexico-Toluca intercity train is strictly based on the costs and monetary revenues of the project. The project revenue is calculated with the potential demand established by the SCT and with the per-user fares for the intercity train in its different segments. The costs of the project are the same as those contemplated in the economic evaluation: costs of investment, maintenance, operation, and acquisition of rolling stock.

ANALYSIS OF THE MEXICO-TOLUCA TRAIN PROJECT

Background. The population of the metropolitan areas of Mexico City and Toluca has grown rapidly in recent decades, causing the number of transfers within the areas and between the two cities to increase in the presence of an obsolete public transport system and with saturated road infrastructure. Today the urban boundaries of both cities have expanded, encroaching on the forests of the Sierra de las Cruces. Thus, on the Toluca side, its metropolitan area has been consolidated absorbing the town of Lerma and Mexico City western area it has spread to the vicinity of La Venta.

Currently, the most important real estate development area in Mexico City (Santa Fe and Interlomas) is collapsed due to the lack of alternatives to access the area due to poor public transport and insufficient road infrastructure, basically limited to four roads: Constituyentes, Reforma, Vasco de Quiroga and the recently opened West motorway. This situation limits the efficient transfer, in terms of cost and time, of the more than 60 thousand daily trips that are generated between Santa Fe and Observatorio.

For its part, Toluca Metropolitan Area composed of 22 municipalities has a population close to 2 million inhabitants and presents a problem of urban expansion with a low population density (INEGI, 2014), which increases its transport needs especially to the city's airport and the Lerma industrial area. Toluca eastern area has two exits to Mexico City: Paseo Tollocan and Avenida de las Torres that join the Mexico-Toluca highway. Public transport in these areas is carried out with low-capacity collective service and intercity bus lines between Toluca and Mexico City.

The problem can be summarized in that everyday thousands of people make trips between Toluca and Mexico City, but congestion both at the exit of Toluca and around Santa Fe and Observatorio in Mexico City, cause a route of 60 kilometers to be made in unfavorable conditions of cost and time. Currently, at peak hour, a trip that begins in Toluca and has as its destination in the west of Mexico City entering through Constituyentes is made in an average time of more than two hours.

To solve this situation, a medium-speed regional passenger train is proposed that connects the Metropolitan Area of Toluca with the west of Mexico City in a safe, fast,

affordable, and sustainable way. Among the benefits of such a project are reduction of travel times, gradual increase in capacity according to demand needs, reduction of impacts on the environment, containment of urban expansion, increase in the share of public transport in the modal split and certainty of regional transport costs,

Project demand *estimation*. The cost-benefit study of the Mexico-Toluca intercity train (SCT, 2013) highlights the diagnosis of the current operation of public and private transport between the Toluca eastern area and the Mexico City western area. It determines the supply of transport in the train corridor and quantifies through surveys and project potential demand models. Table 3 exemplifies the complexity of public transport within and between both cities, such as: the high number of routes, the length of the network, the high travel times, and the low speed of operation of the service.

Concept	Urban Transport		Intercity transport
	Mexico City	Toluca	Mexico City-Toluca
Number of buses	1,147	947	457
Network length (km)	1,363	1,559	1,174
Average cycle time (minutos)	151	182	219
Speed of operation (km/h)	21	20	38
Daily bus tour (km/bus)	111	195	457

Table 3. Indicators of the public transport network studied (72 routes)

Source: Secretariat of Communications and Transport

The project's demand study considers the characteristics and volumes of users who move in the corridor in public and private transport and the results of the survey, this information was used to build the matrix of origin and destination. In addition, modal sharing and travel allocation models were used to estimate demand by mode of transport among project areas.

The potential demand along the intercity train line was divided into three segments: passenger transport within the Toluca Metropolitan Area, from Zinacantepec to Lerma, from Toluca to Mexico City and within Mexico City, from Observatorio to Santa Fe. The demand for public and private transport is determined, as well as the number of users per direction in each segment (Table 4).

Concept \ Segment	Toluca MA	Santa Fe - Observatorio	Toluca - Mexico City	Total	%
Public transport	7,038	62,474	143,177	212,689	92.5%
Private transport	573	5,085	11,654	17,312	7.5%
Total demand	7,611	67,559	154,830	230,000	100.0%
Total daily passengers during the first year (2020)				**230,000**	
Total daily passengers to the evaluation horizon (2050)				**540,000**	

Table 4. Demand for daily passengers of the Mexico-Toluca intercity train

Source: Secretariat of Communications and Transport

Project description. Mexico-Toluca intercity train project consists of a medium-speed railway line construction of 57.7 km in total length, of which 37.0 km are located within the State of Mexico and 20.7 km in Mexico City. The line starts in Zinacantepec, in the western region of the Toluca Valley and ends at Observatorio, within Mexico City, passing through the intermediate stations Pino Suarez, Tecnologico, Lerma and Santa Fe (Figure 1).

Figure 1. Mexico-Toluca intercity train line

Source: Secretariat of Communications and Transport

It is estimated that the project will reduce almost 28 thousand tons of CO_2 emissions per year, save up to 39.2 million dollars a year in road maintenance, create 17 thousand direct jobs, put out of circulation up to 200 thousand vehicles per day, and save 90 minutes per day per user. The service will be carried out with 30 trains of 5 wagons each with a

capacity of 700 passengers in normal schedule and with coupled trains of 10 wagons for 1,400 passengers at peak times, the daily demand met will be 230 thousand in 2020 and 540 thousand in 2050. The train is designed to travel at 160 km/h, the operating speed will be 90 km/h with a travel time of 39 minutes (Table 5).

No.	Station	Distance (kilometers)	Time
1	Zinacantepec	0.0	0'00"
2	Pino Suárez (Bus terminal)	6.1	3'30"
3	Tecnológico (Toluca Airport)	7.0	5'15"
4	Lerma	8.2	4'20"
5	Santa Fe	28.6	18'15"
6	Observatorio	7.8	7'40"
	Total	**57.7**	**39'00"**

Table 5. Distances and travel times of the Mexico-Toluca intercity train

Source: Secretariat of Communications and Transport

Between 2012 and 2018, 18 contracts were awarded for the execution of the studies, designs, release right of way, construction, and project supervision stages. The civil work was budgeted at 1,408.5 million includes three sections of line and workshops, while equipment, track, and electromechanical installations totalize $706.6 million. Civil works, installations and equipment represent 82.8% of the total investment (Table 6).

Concept	Original	Settings	Total	%
Studies, designs and project management	194.8	35.0	229.7	9.0%
Release right of way	68.1	114.8	182.9	7.2%
Construction section I (0-36.1 km)	504.5	121.9	626.4	24.5%
Construction section II (36.1-40.8 km)	142.0	0.0	142.0	5.6%
Construction section III (40.8-57.7 km)	518.3	67.5	585.8	22.9%
Construction of workshops	54.3	0.0	54.3	2.1%
Track and electromechanical installations	478.1	0.0	478.1	18.7%
Rolling stock	228.5	0.0	228.5	8.9%
Induced works	26.6	0.8	27.5	1.1%
Total	**2,215.2**	**339.9**	**2,555.2**	**100.0%**

Table 6. Cost of the Mexico-Toluca intercity train (Million dollars)

Source: Secretariat of Communications and Transport

The railway line construction was divided into three parts: Section I, from the Zinacantepec terminal (km 0.0) to the tunnel entrance under the Sierra de las Cruces (km

36.1), the first 6.6 km are in surface section and the next 29.5 km are in elevated section; Section II, tunnel construction under La Sierra de las Cruces from the western portal (km 36.1) to the eastern portal (km 40.8); and, Section III, from the eastern portal (km 40.8) to the Observatory terminal (km 57.7) in elevated solution.

RESULTS

Economic feasibility. The cost-benefit analysis was carried out by calculating the benefits and social costs generated by the project, evaluating the modification of the current situation in case the construction of the intercity train is executed. The socioeconomic evaluation was carried out under the guidelines established by the Mexican government, the most relevant being the following: constant prices of 2020 were used; evaluation horizon of 34 years, considering 4 years of construction and 30 years of operation, social discount rate of 10%, 2.88% growth rate for the demand´s projection, Travel Times (TT) are considered constant throughout the evaluation horizon, the time social value and the Vehicle Operation Costs (VOC) established by the Mexican Institute of Transport were used. The costs of project execution are investment, maintenance, operation, and acquisition of rolling stock. Economic evaluation does not consider the increase in the value of the properties in areas adjacent to the train line and the terminals, the reduction of accidents and the reduction of polluting emissions such as CO_2.

Project's socio-economic evaluation carried out by the SCT demonstrates its viability in terms of the social and economic benefits, since it obtains a Net Present Value (NPV) of 791.95 million dollars and an Internal Rate of Return (IRR) of 12.9%, higher than the social discount rate established by the Mexican government. Table 7 presents a summary of the project's cash flow showing only the costs and benefits of the first and last year, as well as the profitability results.

Year	Costs (md)			Benefits (md)					Cash flow (md)
	Investment	Operation and mtce.	Total	Savings COV		Savings TT		Total	
				Private T.	Public T.	Private T.	Public T.		
0	-2,555.17	-	-2,555.17	-	-	-	-	-	-2,555.17
1		-46.13	-46.13	40.37	66.49	7.50	250.86	365.21	319.08
30		-62.18	-62.18	94.78	156.11	17.60	588.97	857.46	795.27
Net present value (NPV)									**791.95**
Internal rate of return (IRR)									**12.9%**

Table 7. Cost-benefit analysis of the Mexico-Toluca intercity train (Million dollars)

Financial feasibility. In the financial valuation of the Mexico-Toluca intercity train, the monetary income of the project is estimated from the potential demand determined in the

SCT cost-benefit analysis and the rates per user for the service announced by the agency itself for the different segments. In principle, a fare of $4.61 has been established for the entire trip from Zinacantepec to Observatorio, $0.69 from Santa Fe to Observatorio and $1.15 per trip within the Toluca Metropolitan Area (Table 8).

Concept \ Segment	Toluca MA	Santa Fe - Observatorio	Toluca - Mexico City	Total
Daily passengers	7,611	67,559	154,830	230,000
Cost per trip (dollars)	1.15	0.69	4.61	-
Daily income (dollars)	8,778	46,752	714,302	769,832
Percentage by segment	1.1%	6.1%	92.8%	100.0%
Annual revenue in the first year (million dollars)				**280.99**

Table 8. Mexico-Toluca intercity train revenue estimate

From the structure of revenues and rates by transportation segments is calculated the income of 280.99 million dollars for the first year of service of the intercity train, maintaining the annual growth rate of 2.88% for the project's demand throughout the evaluation horizon, a revenue of 659.71 million dollars is reached in the year 30 of operations. With this income and with the use of the investment, operation and maintenance costs previously used in the economic evaluation, the cash flow of the project financial evaluation is constructed. The financial evaluation demonstrates the feasibility of the project, since the NPV obtained is 14.42 million dollars and the IRR of 10.1% (Table 9).

Year	Costs (md)			Revenue (md)	Cash flow (md)
	Investment	Operation and mtce.	Total		
0	-2,555.17	-	-2,555.17	-	-2,555.17
1		-46.13	-46.13	280.99	234.85
30		-62.18	-62.18	659.71	597.53
Net present value (NPV)					**14.42 md**
Internal rate of return (IRR)					**10.1%**

Table 9. Financial evaluation of the Mexico-Toluca intercity train

It should be noted that both the economic and financial evaluation were carried out with the cost of the project updated by the SCT in December 2018 at 2,555.2 million dollars, when originally 2,215.2 million dollars had been budgeted. In addition, the estimated demand of the project was revised downwards from 274 thousand passengers per day to 230 thousand users per day. That is, both evaluations were made with an updated cost that exceeds the original by 15.3% and with a lower demand by 19.1% with respect to the initially forecast. Despite these circumstances, both types of evaluation determined positive returns

for the intercity train line.

Finally, Figure 2 shows for the financial evaluation the IRR results using different percentages of the daily demand of 230 thousand passengers. For example, a negative IRR of -0.2% is obtained only for a daily demand of 69 thousand passengers, that is, 30% of the predicted demand and for half of the demand (115 thousand daily passengers) an IRR of 3.9% is obtained.

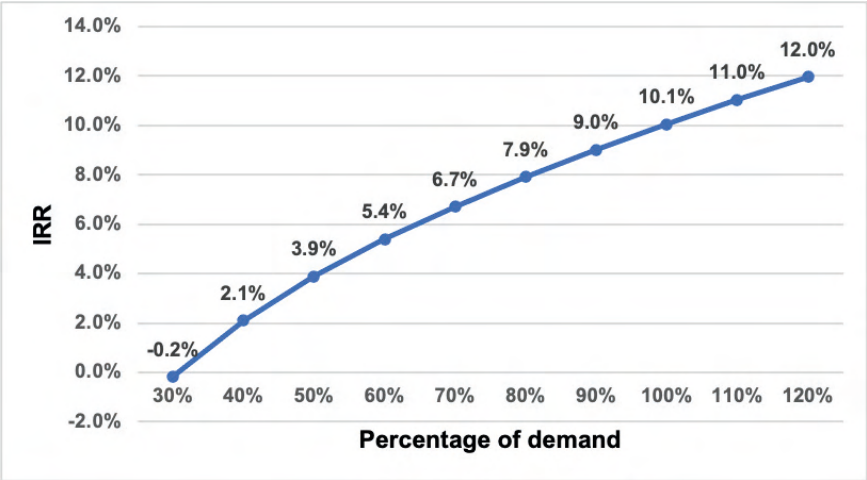

Figure 2. IRR sensitivity analysis for the Mexico-Toluca intercity train

CONCLUSIONS

Railroads concession in Mexico adopted the American pattern of railway operation to integrate mainly the carga service with the United States and Canada, twenty years after the concession process the movement of cargo has doubled, both in tons and in tons-kilometers transported. At present, however, passenger lines account for a very small percentage of the national rail network.

In the current administration, the Mexican authorities planned several passenger rails lines in a context of low public budget, which has led to the priority given to the execution of projects with greater profitability in social and economic terms, eliminating as far as possible the use of subsidies.

Results of the economic evaluation show an adequate socioeconomic profitability of the Mexico-Toluca intercity train construction based on the savings in travel times and the vehicular operation costs of the project's potential users, even though the valuation was carried out at a higher cost than expected and with a lower demand than initially predicted.

If the passenger demand forecasts are met, the results of the financial evaluation of the Mexico-Toluca intercity train demonstrate the long-term viability of the project, indicating that it will be self-financing over a 30-year horizon. The sensitivity analysis only shows low

profitability in case the real demand is less than 30% of the predicted passengers, from this demand it will not be necessary to use public subsidies.

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