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ORIGINAL

Characterisation of fair and sustainable technical fares for public transport in the Guadalajara metropolitan area, Mexico. Case study: Troncal 05. López Mateos

Caracterización de la tarifa técnica, justa y sostenible del transporte público en la metrópoli de Guadalajara, México. Caso: Troncal 05. López Mateos

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ABSTRACT

The study analysed the technical fare of the Integrated Transport Model 'Mi Transporte' on Trunk Road 05. López Mateos in the Guadalajara Metropolitan Area (AMG). Using a quantitative and econometric methodology, the cost structure, revenue and demand elasticities of the system were characterised. The analysis revealed that, with a current fare of MXN $9,50, daily revenues of MXN $707 128 were generated, which covered operating costs with a 15 % margin for transport operators. However, the economic evaluation showed a negative Net Present Value (NPV) and an Internal Rate of Return (IRR) below the Minimum Acceptable Rate of Return (MARR), so investment in the configurations analysed (diesel or CNG) was not recommended. The research also estimated differentiated social fares based on user income, showing that a large part of the population spends between 13 % and 48 % of their income on transport, evidencing a disproportionate burden on low-income households. Furthermore, it was concluded that the route-company model, although more efficient than the old 'man-truck' scheme, requires subsidies and more equitable fare policies to ensure sustainability and accessibility. Finally, the adoption of progressive fares based on ability to pay was proposed, and the need to continue urban mobility studies to support public policy decisions that improve the quality of life in the AMG was emphasised.

Keywords: Technical Tariff; Urban Mobility; Public Transport; Subsidy; Equity.

RESUMEN

El estudio analizó la tarifa técnica del Modelo Integrado de Transporte "Mi Transporte" en la Troncal 05. López Mateos del Área Metropolitana de Guadalajara (AMG). A través de una metodología cuantitativa y econométrica, se caracterizó la estructura de costos, ingresos y elasticidades de demanda del sistema. El análisis reveló que, con una tarifa vigente de $9,50 MXN, se generaban ingresos diarios de $707 128 MXN, lo que permitió cubrir los costos operativos con un margen del 15 % para los transportistas. Sin embargo, la evaluación económica arrojó un Valor Presente Neto (VPN) negativo y una Tasa Interna de Retorno (TIR) por debajo de la Tasa Mínima Aceptable de Rendimiento (TMAR), por lo que no se recomendó la inversión en las configuraciones analizadas (diésel o GNC). La investigación también estimó tarifas sociales diferenciadas según los ingresos de los usuarios, mostrando que una gran parte de la población destina entre el 13 % y el 48 % de su ingreso al transporte, evidenciando una carga desproporcionada para los hogares de bajos recursos. Además, se concluyó que el modelo ruta-empresa, aunque más eficiente que el antiguo esquema "hombre-camión", requiere subsidios y políticas tarifarias más equitativas para garantizar sostenibilidad y accesibilidad. Finalmente, se propuso la adopción de tarifas progresivas basadas en la capacidad de pago y se subrayó la necesidad de continuar con estudios de movilidad urbana para apoyar decisiones de política pública que mejoren la calidad de vida en el AMG.

Palabras clave: Tarifa Técnica; Movilidad Urbana; Transporte Público; Subsidio; Equidad.

INTRODUCTION

Climate change has brought to the forefront the need to reevaluate the current model of resource and energy production and consumption in the economy. An example of this is public transportation, which is usually subsidized and whose increased technical efficiency, understood as the relationship between service production and resource consumption, can help improve public budget management.[1]

Thus, the variables to be quantified are the provision of services (outputs) and the resources consumed in producing those services (inputs). In this sense, the objective of this study is to characterize the technical aspects of the so-called Integrated Transportation Model, “Mi Transporte,” under the route-company scheme in the Guadalajara metropolitan area, specifically Troncal 05. López Mateos (T05) route.

The study analyzes various studies on the technical fare for public transportation, ranging from the international and local context, as well as information obtained from secondary sources such as data from the 2016 National Household Income and Expenditure Survey (ENIGH), prepared by the National Institute of Statistics, Geography, and Informatics (INEGI); as well as data from the Final Report for the Approval of Technical Fares for Collective Passenger Transport Services for Routes-Companies in the Guadalajara Metropolitan Area (AMG), the Integrated System of the City of Puerto Vallarta, and the User Satisfaction Survey for the AMG, the latter issued by the now defunct Institute of Mobility and Transportation of the State of Jalisco (IMTJ) between 2016 and 2018, which will enable the analysis of urban mobility, transportation, and territory.[2]

In addition, using a quantitative methodology, the study provided an analysis of demand elasticities and indicators of metropolitan urban transport services to determine the impact of public transport fares on users and the sector during the 2018-2019 period. In addition, an economic evaluation of the trunk public passenger transport corridors of the General Transport Program of the State of Jalisco (PGT) was carried out, developing a model based on three criteria: 1) Evaluate the operating cost structure generated by the production of the service; 2) Calculate and measure the income obtained from the production of the service; and 3) Assess the three primary financial indicators.[3,4]

This provided a theoretical and technical contribution that made it possible to answer the research questions: How does the so-called “Mi Transporte” Integrated Transport Model, under the route-company scheme, contribute to achieving a technical, fair, and sustainable fare for public transport in the Guadalajara metropolitan area, in the case of Trunk Line 05? López Mateos? What is the cost structure of the “Mi Transporte” Integrated Transport Model, which operates under the route-company scheme in the Guadalajara metropolitan area, in the case of Troncal 05? López Mateos? And how do demand, competition, and public urban mobility and transportation policies influence the fare of the “Mi Transporte” Integrated Transportation Model, which operates under the route-company scheme in the Guadalajara metropolitan area, in the case of Troncal 05? López Mateos?

Elasticity is a crucial indicator for both the public transport sector and the State. This indicator enables the anticipation of market behavior in response to changes in factors such as fares.[5]

In this sense, the results obtained allow decision-makers and public transport operators to understand better how to set fair and sustainable technical fares, as well as to analyze the main challenges in the sector that should be considered in future urban mobility, transport, and land use projects in the Guadalajara Metropolitan Area (AMG).

Figure 1. Units on the Troncal 05 route

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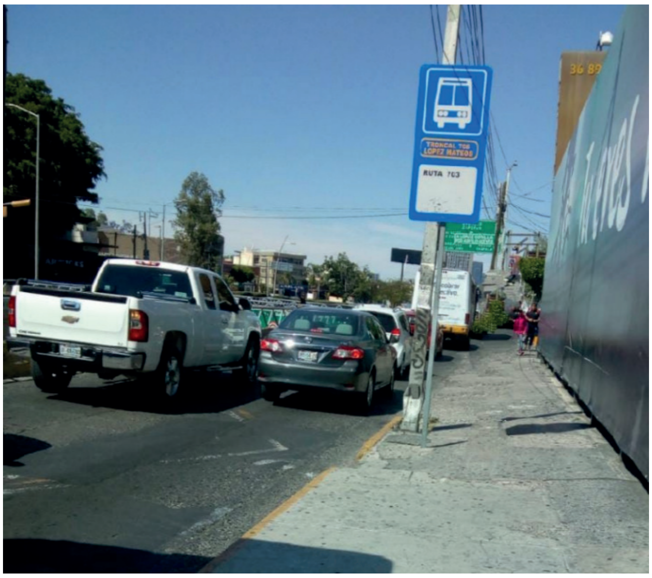

Figure 2. Troncal 05 bus stop. López Mateos

Problem statement

In the early 19th century, following the Industrial Revolution, Mexico's metropolises began to implement tram systems to meet the public transportation needs. However, the boom in rail systems, both urban (trams) and interurban (railways), was gradually replaced by the automobile.[1,2,3] In other words, while the road network spread throughout the country, in cities, the tram declined as a basic system, a trend that accelerated during the 1930s. However, the need for mobility was quickly replaced by buses.[1]

Bus networks are certainly easier and less expensive to implement than rail networks, due to the purchase of rolling stock, flexibility in line design, and the installation of stops.[4,5,6] On the other hand, tram, metro, light rail, and heavy rail networks require more careful planning, greater investment in rolling stock, maintenance, and infrastructure, and place a significant burden on public administrations.[2] Meanwhile, buses are currently competing with trams and light rail systems in terms of efficiency and quality of service.[3,4] Along with electricity and water supply, solid waste collection, and street and avenue maintenance, bus services are one of the primary services required by the population.[7,8] In short, urban public transport, provided by buses, is a tool for various activities, including work, training, shopping, and leisure.[5]

According to Islas et al.[6], in Mexico, the nature of the public transport service offered is often deficient. This has led to the formation of public monopolies or concession systems, which ultimately reduce competition and lead to lower service quality. Furthermore, research on this topic has rarely analyzed fares in depth; that is, it has focused mainly on the technical aspects of operation.[9,10,11] Hence, the importance of identifying the socioeconomic aspects of users in the search for solutions to transportation problems is evident.[12,13,14]

In 1925, according to Alvizo[7], Guadalajara saw the birth of its first bus transport cooperative. The company, founded by Miguel Colunga, Agustín Zúñiga, and several drivers, began operations with second-hand vehicles, covering three main routes: Centro-Colonias, Oblatos-Centro, and Mexicaltzingo-Mezquitán. Subsequently, the Compañía Occidental de Transportes acquired the electric trams and replaced them with internal combustion buses.[15,16,17]

Moving forward to 1963, Cárdenas[8] notes that the first major infrastructure works were carried out to establish the Collective Transportation System (STC). By 1971, almost 1,7 million passengers, representing 85 % of the city's total users, traveled daily on 1858 buses owned by private concessionaires.[18] These buses carried an average of 911 passengers per day, which was favorable for business owners but problematic for users due to the high fares.[9,19]

Due to the growing complexity of the STC, SISTECOZOME was established in 1976 as a decentralized agency responsible for managing public transportation. From its inception, this agency functioned poorly, and according to El Informador, it only managed to transport between 1,5 % and 7 % of the city's total users. This situation highlighted the need for state intervention in financing transportation in the Guadalajara Metropolitan Area.[20,21,22]

In this regard, given the historical evolution of the public transportation system in Guadalajara, it is clear that the issue of fares has been a persistent point of contention between business interests and societal needs. Since the 1970s, when private buses transported the majority of users at an increasingly high cost, the need for government intervention in setting fares has been evident.[23,24,25] As fares increased, the impact on low-income users became more palpable, highlighting an uncomfortable reality: business profitability and social welfare are often conflicting goals in the field of public transportation.

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In this context, government subsidies for transportation fares emerge as a viable and necessary solution to balance this equation. A subsidy would alleviate the financial burden on users, especially the most vulnerable, without compromising the economic viability of transportation operators. This type of intervention is not only desirable but imperative to ensure an efficient, inclusive, and, above all, fair public transportation system for all citizens.[26,27,28]

The case of Guadalajara reinforces the premise that public transportation is an essential service that requires careful regulation and financial support from the state to function optimally.[29,30,31] In short, fare subsidies are a key strategy for reconciling business demands with social needs, ensuring that public transport continues to be a driver of mobility and, therefore, of development for the entire city.[32,33,34]

In Brussels, for example, according to Ferri[10], the public transport operator in the metropolitan area allows all children under the age of eleven to travel free of charge, offers discounts to students and even non-students, as well as loyalty bonuses. In short, Belgian workers enjoy an annual pass valid for the entire rail network, co-financed by their company. Part of the cost of the metro operator's pass is subsidized by the worker's company, with a contribution that can cover the entire price. Lujan[11] mentions that RATP (the French acronym for the company that manages public transport in the Paris metropolitan area) allows all children under the age of four to travel for free and children up to the age of ten to travel at half price. Students under the age of 26 are also entitled to a 47,63 % discount on standard pass prices with a special pass called Imagine R.[35,36,37]

Currently, in Jalisco, specifically in the Guadalajara Metropolitan Area (AMG), the second largest in terms of population in Mexico, there are ten municipalities:[38,39,40] Guadalajara, Zapopan, San Pedro Tlaquepaque, Tonalá, El Salto, Tlajomulco de Zúñiga, Ixtlahuacán de los Membrillos, Juanacatlán, Zapotlanejo, and Acatlán de Juárez. Economic conditions require the rational use of public funds. The public transport system is a sector that requires significant investments and whose service provision is overburdened. In addition, the old "man-truck" public transport model had several weaknesses in its management, including customer service, user information, human resources, operations, maintenance, operating costs, and service management administration.[41,42,43]

In this regard, to prevent transport companies from demanding public investment, the functional and technical efficiency of transport must be increased. This can be achieved by optimizing the relationship between service production and resource consumption, thereby enabling better budget management for the sector.[44,45] Therefore, to improve urban mobility, a methodology must be developed to evaluate the functional and technical efficiency of public transport companies, specifically those operating routes in the AMG.[46]

In 2013, the Jalisco State Road, Traffic, and Transportation Services Act was replaced by the Jalisco State Mobility and Transportation Act. In this vein, the transition from the man-truck model to the route-company model sought to improve mobility, benefiting the quality of life for the inhabitants of the AMG.[47,48]

However, mobility problems in the AMG have substantially reduced the quality of life of its citizens. This is caused by the high rate of motorization resulting from inadequate urban development and mobility policies promoted by the authorities, generating a significant number of negative externalities (air pollution, climate change, accidents and fatalities, congestion, and noise).[49,50] Therefore, it is believed that as the transport sector manages to respond to the new challenges of physical, operational, fare, and subsidy integration, progress and improvements can be achieved not only at the business level, but also at the social and environmental levels.[51,52]

According to the Jalisco Institute of Statistical and Geographic Information (IIEG), in 2019, Jalisco was considered the fourth-largest state economy in Mexico. According to data from the National Population Council (CONAPO), in 2019, the state had a total population of nearly 8,4 million inhabitants, of which approximately 61 % (5 million inhabitants) are concentrated in the AMG.[53,54] This ranks second among the most populated metropolitan areas in our country.[12]

On the other hand, according to data from the Metropolitan Land Use Plan (POTmet), various industrial, commercial, and cultural activities are carried out in the urban area of the AMG, making this population center one of the most important in the country.[55,56] However, this phenomenon presents multiple mobility and sustainability challenges, as the expansion has been significantly removed from the existing mass public transport structure.[13]

Contrary to the above, Guzmán et al.[14] argue that public transport systems have been characterized by demanding growth parallel to that of cities.

Based on the above arguments, it appears that the mobility problems that have accumulated since the 1970s remain unresolved.[57,58,59] Although it can be said that the Jalisco government has never neglected this area, its decisions have been overtaken by urban growth and, above all, the intensive use of cars. It is necessary to provide references to support this argument.[60,61,62] In the first scenario, these trends generate what are known as urban mobility externalities, i.e., traffic congestion, high accident rates, environmental pollution, and noise pollution, as well as the deterioration of public spaces.[63,64,65] In turn, urban mobility problems have also had a direct impact on a society's ability to access essential activities, such as work, education, culture, and recreation, which are crucial for promoting the comprehensive development of citizens.[66,67,68]

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According to the Multimodal Travel Demand Study for the ZMG(15), 3 042 719 inhabitants made 9 752 652 trips daily, resulting in 2,48 visits per capita. In this regard, mobility in the Guadalajara Metropolitan Area (ZMG)4 in 2007 was as follows: 37,4 % of trips were made on foot, 28,3 % by public transport, 27,2 % by private transport, 2,2 % by bicycle, 1,1 % by staff transport, 0,9 % by taxi, 0,5 % by school transport, 0,5 % by motorcycle, and 1,7 % unspecified.(69,70,71)

However, for 2015, the INEGI intercensal survey shows that the modal share in the ZMG changed, with mass public transport now gaining ground. Private vehicles are the second most commonly used means of transport for commuting to work (32 % of trips) and the third for school trips (21 % of trips), with public transport or walking being the most critical options.(72,73,74) Moreover, for 2019, according to data from the study "Getting Around in GDL. Report on the results of the Citizen Perception Survey on Quality of Life conducted by Jalisco Cómo Vamos in the Guadalajara Metropolitan Area in 2016, with a focus on mobility," by the Jalisco Cómo Vamos group, revealed that 60 % of people in Guadalajara mainly use public transportation.(16,75)

In addition, according to the National Survey of Household Income and Expenditure in Mexico conducted by INEGI(17), households in the AMG spend an average of 14,30 % of their income on public transportation. However, lower-income households, which are in the lowest decile, spend nearly 48 % of their income on housing.

Likewise, in European cities such as Madrid and London, mass mobility has not only become an effective model for comprehensive transformation, but also an indispensable instrument of public policies aimed at human and sustainable development. However, managing a new urban mobility model in a comprehensive and participatory manner also represents a challenge for citizens and their government.(76,77,78,79)

De Rus et al.(18) argue that choosing an alternative public transportation system is not relevant unless it leads to a substantial reduction in operating costs. However, capital costs are equally crucial; in the field of mass transportation, infrastructure spending is a decisive factor in decision-making.(80,81,82,38) For example, in the Man Truck model, where each licensee manages capital and infrastructure costs individually for their buses, it is not easy to achieve the efficiency derived from the economies of scale offered by a Route-Company model.(84,85,86,87) The latter allows for a reduction in capital and infrastructure costs, which, from a financial and operational perspective, is essential to ensure the economic viability of the routes.(88,89,90)

Based on the above, it is clear that the AMG suffers from the following problems: rapid and scattered urban growth, growth of the vehicle fleet, frequent unacceptable pollution levels and significant damage to overall health; increased traffic and travel times, as well as longer travel distances,(91,92,93,94) low population density, and a disjointed and obsolete transport model (the "man-truck" model), which the route-company model is currently replacing in an attempt to take advantage of some of the management and efficiency benefits of BRT.(95,96,97,98)

Figure 3. Complementary route units during the pandemic

As a result, in 2019, the Jalisco government reorganized its transportation system through the Ministry of Transportation (SETRAN) with the General Transportation Program of the State of Jalisco (PGT), which includes the implementation of 18 trunk corridors.(99,100,101,102) Based on a non-probabilistic sample, trunk corridor 05, López Mateos, was selected to obtain detailed information because, in the Guadalajara Metropolitan Area,(103,104) this corridor has been identified as a critical axis for public transportation.(105,106,107,108) This corridor serves a considerable population and connects multiple municipalities with downtown Guadalajara, an urban center with a high concentration of employment.(109,110,111,112) However, the efficiency and effectiveness of the current service are suboptimal due to fragmented management of existing routes and the lack of integrated infrastructure.(113,114,115,116)

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Additionally, the fragmented management and inadequate public transport infrastructure on the Troncal 05 López Mateos route are not effectively meeting the mobility needs of the population or capitalizing on the area's economic potential.[117,118,119,120] This raises the need to evaluate the economic factors that justify selecting this trunk line as a priority project.[121,122,123,124,125]

According to the Jalisco State Institute of Mobility and Transportation (IMTJ) for 2014,[126,127,128] 13 public transportation routes operated on the Troncal 05 corridor. López Mateos (T05) had 13 public transport routes, of which nine originated in the municipality of Tlajomulco de Zúñiga and used López Mateos Avenue as their main corridor to reach their destinations, which were mainly concentrated at the Old Bus Station in the municipality of Guadalajara. The remaining routes originate from the north of the Guadalajara Metropolitan Area, with three routes coming from Huentitán and one from Zapopan Norte.

Table 1. Routes in operation in the Troncal 05 Corridor. López Mateos, 2014

No	Route
1	2
2	79
3	182 Lomas del Sur
4	182 Balcones
5	182A Ojo de Agua
6	183 Lomas de San Agustín
7	183A Hacienda de Santa Fe - Santa Anita
8	186 Eucalyptus Trees - La Noria
9	186 Valley of the Emperors
10	186 (382) López Mateos (La Noria)
11	258
12	258A
13	258D

The Corridor of Route Troncal 05. López Mates is approximately 25,86 km long and 32,80 km wide, covering 59 neighborhoods in Guadalajara, 75 neighborhoods in Tlajomulco de Zúñiga, six neighborhoods in San Pedro Tlaquepaque, and 70 neighborhoods in Zapopan. It also connects with lines 1 and 2 of the light rail system at the Macrobús and MIBici stations, as well as with bike lanes.[129,130,131,132]

Likewise, according to data from the IMTJ[17] and the INEGI Population and Housing Census, the Corridor of Route Troncal 05. López Mateos, with a coverage radius of 400 meters, serves around 738 836 inhabitants who travel to the center of the municipality of Guadalajara, which has 430 744 sources of employment, making it a trunk line that generates a large number of work-related trips.[133,134,135,136]

Figure 4. Work-related trips to the center of the municipality of Guadalajara

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Research questions

- How does the so-called "Mi Transporte" Integrated Transport Model, under the route-company scheme, contribute to achieving a technical, fair, and sustainable fare for public transport in the Guadalajara metropolitan area? Case Troncal 05. López Mateos?
- What is the cost structure of the "Mi Transporte" Integrated Transport Model, which operates under the route-company scheme in the Guadalajara metropolitan area? Case Troncal 05. López Mateos?

General objective

- To characterize the technical, fair, and sustainable fare for public transportation known as the "Mi Transporte" Integrated Transportation Model, under the route-company scheme in the Guadalajara metropolitan area, specifically Troncal 05. López Mateos.

Figure 5. Electric vehicles

METHOD

This research was conducted through the implementation of a methodological and instrumental proposal. It consisted of applying a utility model designed to characterize fair and sustainable technical fares. The sample was selected using a non-probabilistic method, opting for convenience and availability of operational data, which led to the choice of Trunk Route 05, known as López Mateos.

The methodology used to achieve the objectives established in this thesis was divided into four stages. Each of these stages was aligned with the objectives mentioned in Chapter I, sub-section I.5 "Objectives of this thesis."

Etapa	Descripción
Etapa 1: Caracterización de la tarifa técnica, justa y sostenible	1. Revisión bibliográfica y documental sobre el Modelo Integrado de Transporte "Mi Transporte" y el esquema ruta-empresa en la Troncal 05. López Mateos.
	2. Identificación y análisis de las principales variables que influyen en la determinación de la tarifa técnica, como costos de operación, infraestructura, demanda de usuarios y políticas públicas.
	3. Recopilación y análisis de datos históricos y actuales sobre tarifas técnicas y tarifas aplicadas en la Troncal 05. López Mateos y otras troncales del modelo "Mi Transporte".
	4. Comparación de tarifas técnicas y aplicadas en distintas troncales y sistemas de transporte para identificar posibles patrones y áreas de mejora.
Etapa 2: Dimensionamiento del comportamiento de los principales costos de operación	1. Identificación de componentes clave de los costos de operación del Modelo Integrado de Transporte "Mi Transporte" en la Troncal 05. López Mateos, incluyendo combustible, mantenimiento, personal, seguros, entre otros.
	2. Recopilación y análisis de datos históricos y actuales de los costos de operación en la Troncal 05. López Mateos.
	3. Análisis de tendencias y correlaciones entre los costos de operación y las tarifas aplicadas a lo largo del tiempo.
	4. Identificación de factores externos que puedan afectar los costos de operación, como variaciones en el precio del combustible o cambios en políticas gubernamentales.
Etapa 3: Explicación del esquema tarifario	1. Investigación y descripción del esquema tarifario vigente en el Modelo Integrado de Transporte "Mi Transporte" del AMG, incluyendo estructura de precios, subsidios, tarifas diferenciadas y mecanismos de actualización.
	2. Análisis del impacto del esquema tarifario en diferentes grupos de usuarios, considerando aspectos socioeconómicos, geográficos y demográficos.

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	3. Comparación del esquema tarifario del AMG con esquemas de otras ciudades o sistemas de transporte similares, resaltando similitudes y diferencias.
Etapa 4: Elaboración del modelo econométrico y de evaluación económica	1. Selección de variables relevantes para el modelo econométrico, incluyendo costos de operación, demanda de usuarios, indicadores de servicios de transporte y variables macroeconómicas, entre otras.
	2. Recolección y procesamiento de datos necesarios para alimentar el modelo econométrico, asegurando su calidad y representatividad.
	3. Estimación de elasticidades de demanda y otros parámetros relevantes utilizando técnicas econométricas apropiadas, como regresión múltiple o modelos de series temporales.
	4. Cálculo de la tarifa técnica, justa y sostenible para la Troncal 05. López Mateos, utilizando el modelo econométrico desarrollado y los resultados de las elasticidades de demanda e indicadores de servicios de transporte.
	5. Realización de análisis de sensibilidad para evaluar la robustez del modelo y explorar posibles escenarios futuros según variaciones en las variables clave.
	6. Comparación de resultados del modelo con las tarifas técnicas y aplicadas en la Troncal 05. López Mateos y otras troncales del modelo "Mi Transporte".
	7. Proposición de recomendaciones para la implementación de una tarifa técnica, justa y sostenible en la Troncal 05. López Mateos y, si es aplicable, en otras troncales del Modelo Integrado de Transporte "Mi Transporte" del AMG.

Figure 6. Stages of the methodology

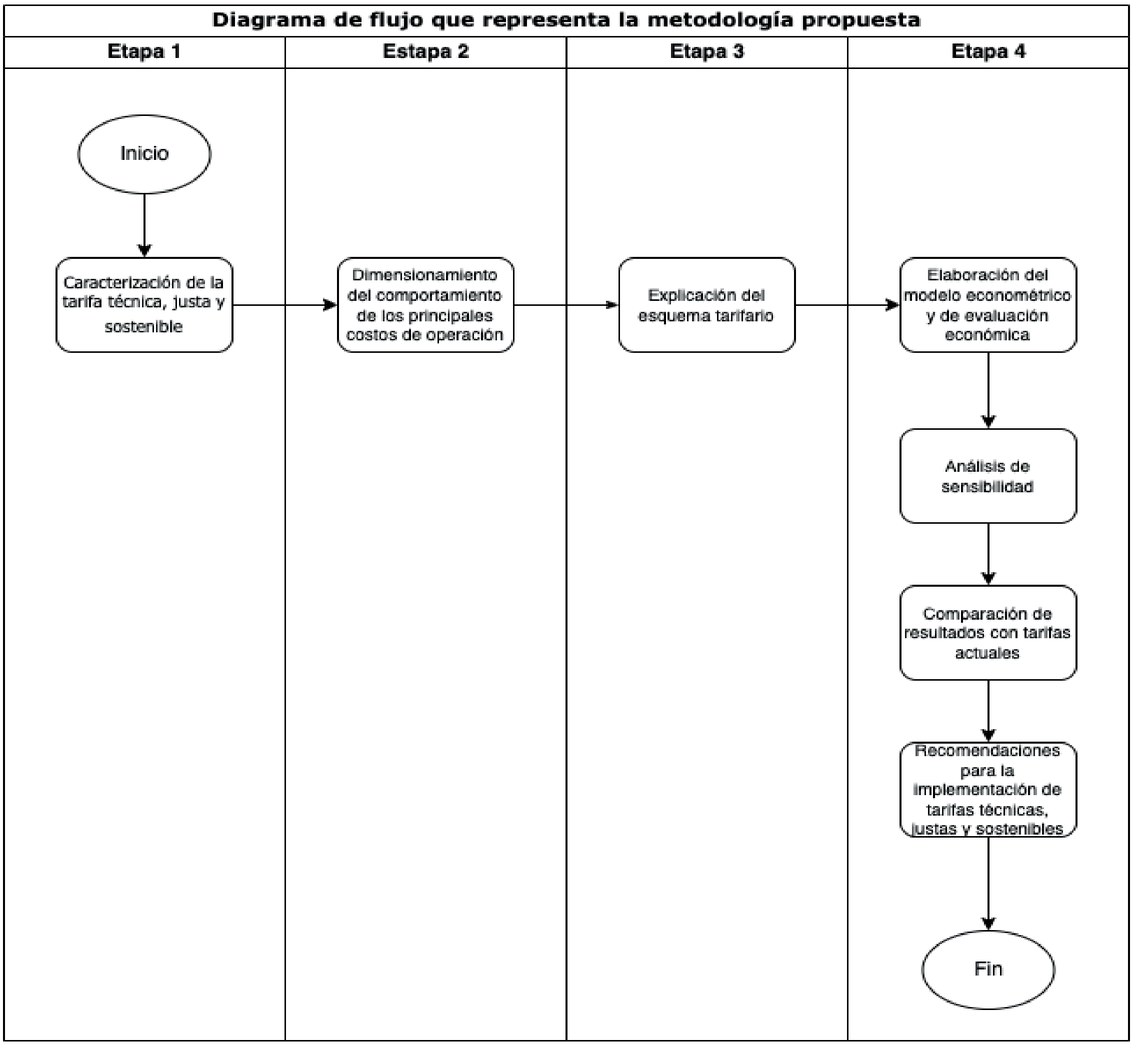


Figure 7. Flow chart of the proposed methodology

The flowchart illustrates a sequential and structured process that follows each stage of the methodology, from characterizing the fare to developing recommendations. At each stage, specific analyses were carried out to inform the subsequent stages. This approach ensured that the methodology efficiently and effectively addressed the objectives set out in the thesis.

Additionally, its implementation provided relevant and detailed information on the technical, fair, and sustainable fare for Trunk Line 05. López Mateos and, potentially, on other trunk routes of the General Transportation Program (PGT) of the AMG's SETRAN[19]. The study's results could help inform decision-makers about potential adjustments to fare and public transportation policies.

Stage 1: Characterization of the technical, fair, and sustainable fare

General Transport Program Offer

In 2019, the Jalisco government reorganized its transportation system through the Transportation Secretariat (SETRAN) with the General Transportation Program of the State of Jalisco (PGT), which includes the implementation of the following trunk corridors: Trunk 01. 18 de Marzo, Trunk 02. Artesanos, Trunk Line 03. Belisario, Trunk Line 04. Lázaro Cárdenas, Trunk Line 05. López Mateos, Trunk Line 06. Pablo Valdez, Trunk Line 07. Enrique Díaz de León, Trunk Line 08. Américas, Trunk Line 09. Circunvalación, Trunk Line 10. Mariano Otero, Trunk Line 11. Río Nilo – Guadalupe, Trunk Road 12. Vallarta, Trunk Road 13. Solidaridad, Trunk Road 14. 8 de Julio, Trunk Road 15. Prolongación Alcalde, Trunk Road 16. Juan Gil Preciado, Trunk Road 17. Patria and Trunk Road 18. Washington. This offer is described in the following table with its specific characteristics:

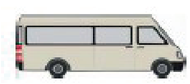
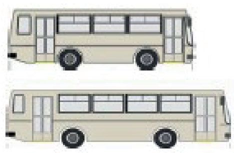
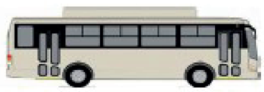
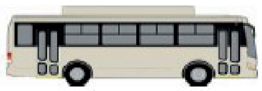
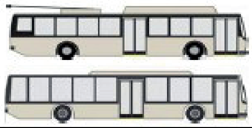
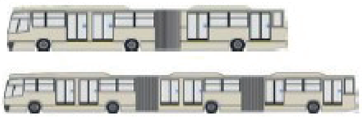
Troncal	Modalidad	Longitud Ida y Vuelta (Km)	Tiempo de recorrido (Min.)	Frecuencia de paso en (Min.)	Parque vehicular	Vueltas programadas
T01. 18 de Marzo	Troncal 01	41.3	151	6.0	25	7
T02. Artesanos	Troncal 02	35.0	128	7.1	18	8
	Alimentador 02-02	23.1	87	21.6	4	11
T03. Belisario	Troncal 03	44.9	163	6.5	25	6
T04. Lázaro Cárdenas	Troncal 04	42.4	155	3.1	50	6
	Alimentador 04-01	66.7	241	10.0	24	4
	Alimentador 04-02	64.0	231	8.2	28	4
	Alimentador 04-03	27.1	101	8.4	12	10
T05. López Mateos	**Troncal 05**	**62.2**	**224**	**4.3**	**48**	**4**
	Troncal 05 A	**76.4**	**275**	**7.2**	**49**	**4**
	Alimentador 05-01	**59.3**	**214**	**11.9**	**1**	**5**
	Alimentador 05-02	**39.1**	**143**	**7.2**	**6**	**7**
	Alimentador 05-03	**43.8**	**160**	**10.0**	**7**	**6**
	Alimentador 05-04	**54.0**	**196**	**9.8**	**15**	**5**
	Alimentador 05-05	**24.1**	**90**	**7.5**	**2**	**11**
	Alimentador 05-06	**45.2**	**155.2**	**7**	**12**	**6**
T06. Pablo Valdez	Troncal 06	41.2	150	5.0	30	7
	Alimentador 06-01	25.6	96	8.0	12	10
	Alimentador 06-02	36.5	134	7.9	17	7
	Alimentador 06-03	28.4	105	7.0	15	9
T07.Enrique Díaz de León	Troncal 07	58.6	212	3.5	60	5
	Alimentador 07-01	36.8	135	5.2	26	7
	Alimentador 07-02	36.2	133	10.2	13	7
	Alimentador 07-03	22.1	83	4.9	17	12
T08. Américas	Troncal 08	39.5	144	4.2	34	7
T09. Circunvalación	Troncal 09 Circuito 1	50.7	184	4.0	46	5
	Troncal 09 Circuito 2	36.3	133	3.9	34	7
T10. Mariano Otero	Troncal 10	33.6	124	4.1	30	8
	Alimentador 10-01	47.9	174	7.9	22	6
	Alimentador 10-02	23.8	89	8.1	11	11

T11. Río Nilo - Guadalupe	Troncal 11A	31.2	115	4.1	28	9
	Alimentador 11A-01	38.2	140	10.0	14	7
	Alimentador 11A-02	40.2	147	10.5	14	7
	Alimentador 11A-03	43.0	157	10.4	15	6
	Troncal 11B	35.7	131	4.7	28	8
	Alimentador 11B-01	43.7	159	14.5	11	6
	Alimentador 11B-02	15.1	58	7.3	8	17
	Alimentador 11B-03	25.5	95	7.9	12	10
T12. Vallarta	Troncal 12	43.4	158	5.9	27	6
	Alimentador 12-01	53.3	193	7.7	25	5
	Alimentador 12-02	26.0	97	6.1	16	10
T13. Troncal Solidaridad	Troncal 13	71.5	257	1.5	169	4
	Troncal 13 A	62.9	227	3.0	76	4
	Troncal 13 B	50.4	183	3.7	50	5
	Alimentador 13-01	51.1	185	6.2	30	5
	Alimentador 13-02	20.6	78	9.7	8	13
	Alimentador 13-03	29.0	107	6.0	18	9
	Alimentador 13-04	29.4	109	21.7	5	9
	Alimentador 13-05	38.0	139	15.5	9	7
	Alimentador 13-06	46.4	169	15.3	11	6
	Alimentador 13-07	35.3	130	11.8	11	8
	Alimentador 13-08	14.9	58	9.6	6	17
	Alimentador 13-09	29.5	109	9.1	12	9
T14. 8 de Julio	Troncal 14	55.8	202	2.4	85	5
	Alimentador 14-01	21.0	79	6.1	13	13
	Alimentador 14-02	56.4	204	10.2	20	5
	Alimentador 14-03	20.7	78	5.6	14	13
	Alimentador 14-04	44.7	163	6.5	25	6
	Alimentador 14-05	14.6	56	9.4	6	18
	Alimentador 14-06	26.3	98	6.1	16	10
	Alimentador 14-07	12.4	49	4.9	10	20
T15. Prolongación Alcalde	Alimentador 15-01	37.7	138	6.9	20	7
	Alimentador 15-02	29.9	111	5.0	22	9
	Alimentador 15-03	24.1	90	6.0	15	11
	Alimentador 15-04	26.7	99	8.3	12	10
	Alimentador 15-05	35.9	132	6.0	22	8
	Alimentador 15-06	32.6	120	5.0	24	8
T16. Juan Gil Preciado	Troncal 16	42.7	156	3.0	52	6
	Alimentador 16-01	44.1	161	5.4	30	6
	Alimentador 16-02	35.8	131	10.1	13	8
	Alimentador 16-03	35.1	129	10.7	12	8
	Alimentador 16-04	39.6	145	14.5	10	7
	Alimentador 16-05	39.3	144	8.0	18	7
	Alimentador 16-06	47.6	173	7.9	22	6
	Alimentador 16-07	60.6	219	12.2	18	5
T17. Patria	Troncal 17 A	55.9	202	4.4	46	5
	Alimentador 17A-01	38.4	141	3.3	42	7
	Alimentador 17A-02	44.2	161	7.3	22	6
	Alimentador 17A-03	22.0	82	11.8	7	12
	Troncal 17 B	32.1	118	9.1	13	8
	Alimentador 17B-01	28.7	106	9.7	11	9
T18. Washington	Troncal 18 Circuito 1	54.3	197	4.1	48	5
	Troncal 18 Circuito 2	55.5	201	4.0	50	5

Source: Jalisco State Institute of Mobility and Transportation[20]

Figure 8. Operational characteristics of the trunk roads of the General Transportation Program of the State of Jalisco

The vehicles offered by the public passenger service in the Guadalajara Metropolitan Area, which the Jalisco State General Transport Program refers to as "Trunk and Complementary," will be vehicles in segments "B" and "C" as described in the current General Technical Regulations (NGCT). These vehicles are shown in figure 9.

TIPO DE VEHÍCULO	SEGMENTO	TIPO DE SERVICIO	CARACTERÍSTICAS
	SEGMENTO A	CUENCA DE SERVICIO	**PESO BRUTO VEHÍCULAR** 5,000 kg. máximo **CAPACIDAD NOMINAL** 9 pasajeros como minimo 20 como máximo -Incluye conductor- Todos deben ir sentados **COMBUSTIBLE** Gasolina / Diesel
	SEGMENTO B 7.50 a 9.50 m	ALIMENTADORA - CUENCA DE SERVICIO ALIMENTADORA	**PESO BRUTO VEHÍCULAR** 10,400 kg - 14,000 kg **CAPACIDAD NOMINAL** 50 a 75 Pasajeros **COMBUSTIBLE** Gas natural comprimido (GNC) / Diesel
	SEGMENTO C 9.51 a 12.50 m	TRONCALES	**PESO BRUTO VEHÍCULAR** 14,000 kg a 18,600 kg **CAPACIDAD NOMINAL** 100 pasajeros como máximo. No se permite personas de pie en área inmediata al conductor ni en área de ascenso y descenso **COMBUSTIBLE** Gas Natural comprimido (GNC) / Diesel ultra bajo azufre (UVA)
	SEGMENTO C 10.30 a 12.50 m	CARATERÍSTICAS ESPECIALES TRONCALES - CORREDORES	**PESO BRUTO VEHÍCULAR** 14,000 kg a 18,600 kg **CAPACIDAD NOMINAL** Desde 37 hasta 45 pasajeros con igual número de asientos, no se permite que personas viajen de pie **COMBUSTIBLE** Gasolina / Diesel ultra bajo azufre (UVA)
	SEGMENTO D 9.51 - 12.50 m	TRONCALES	**PESO BRUTO VEHÍCULAR** 19,000 kg. máximo **CAPACIDAD NOMINAL** 100 a 110 pasajeros como máximo. No se permite personas de pie en área inmediata al conductor ni en área de ascenso y descenso. **COMBUSTIBLE** Trolebus: Energía Eléctrica . Híbridos: Diesel o gas y energía eléctrica
	SEGMENTO E 18.50 m - 25 m	CORREDORES	**PESO BRUTO VEHÍCULAR** E1: 30,500kg máx. E2: 39,500kg máx. **CAPACIDAD NOMINAL** E1: 165 pasajeors E2: 240 pasajeros como máximo. No se permite personas de pie en área inmediata al conductor ni en área de ascenso y descenso **COMBUSTIBLE** Diesel ultra bajo azufre (UVA)

Source: Jalisco State Institute of Mobility and Transportation[20]

Figure 9. Vehicle types and characteristics required by the NGCT for the operation of trunk and complementary routes

It should be noted that both segment "B" and "C" vehicles, which will make up the trunk and complementary routes, must have 10 % of their units equipped with ramps for people with disabilities. Likewise, the nominal capacity of vehicles (cnv) in segment "B" is 75 passengers and 60 passengers with a ramp, and for segment "C", it is 92 passengers and 77 passengers with a ramp.

In this regard, according to studies carried out by the Jalisco State Institute of Mobility and Transportation (IMTJ) during 2018, it was determined that the average working time of public transportation units is 15,5 hours per day ($HrTd$), which is equivalent to 5657,5 hours worked on average per year and an average travel speed of 16 km/hr for the AMG.

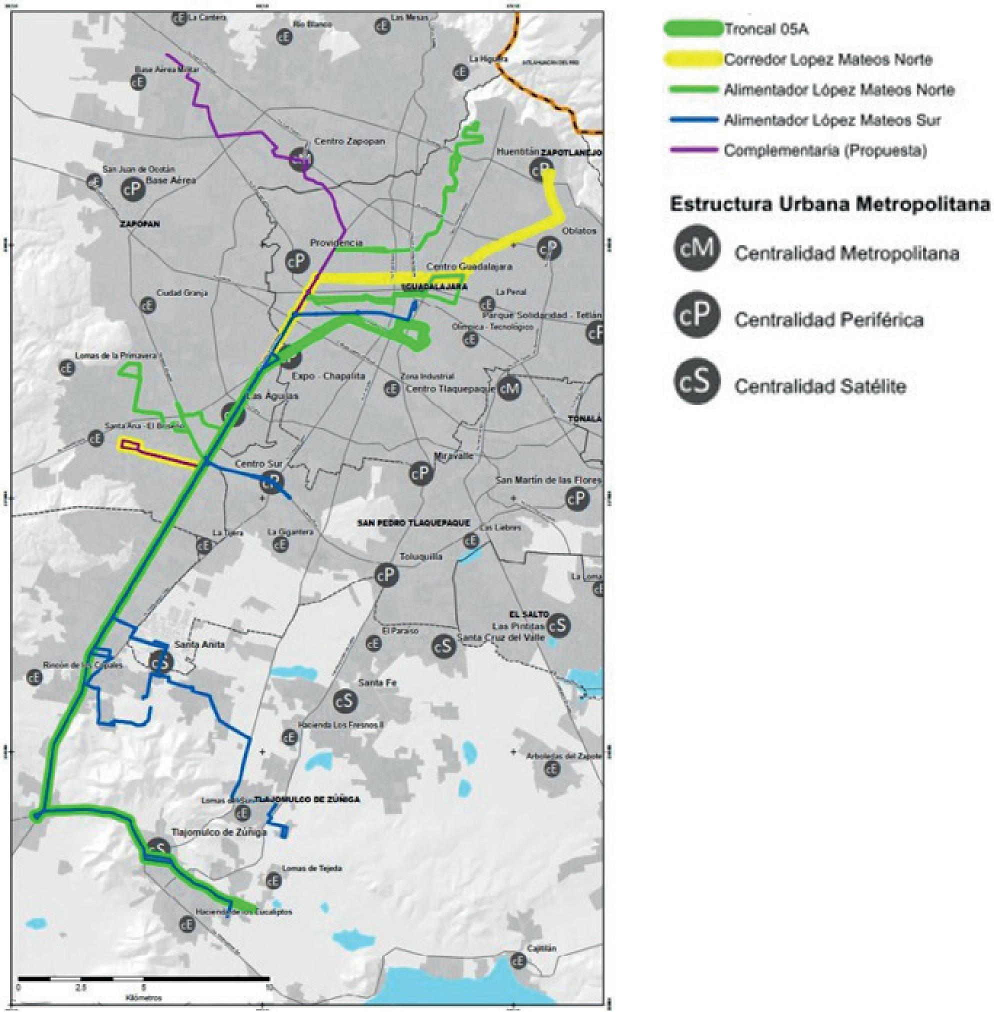
Trunk Road 05. López Mateos

Delimitation of the study area of T05. López Mateos

According to the Guadalajara Metropolitan Area Planning and Development Management Institute (IMEPLAN), the T05 López Mateos trunk route was updated for 2019 and now covers the municipalities of Guadalajara, Zapopan, San Pedro Tlaquepaque, and Tlajomulco de Zúñiga.

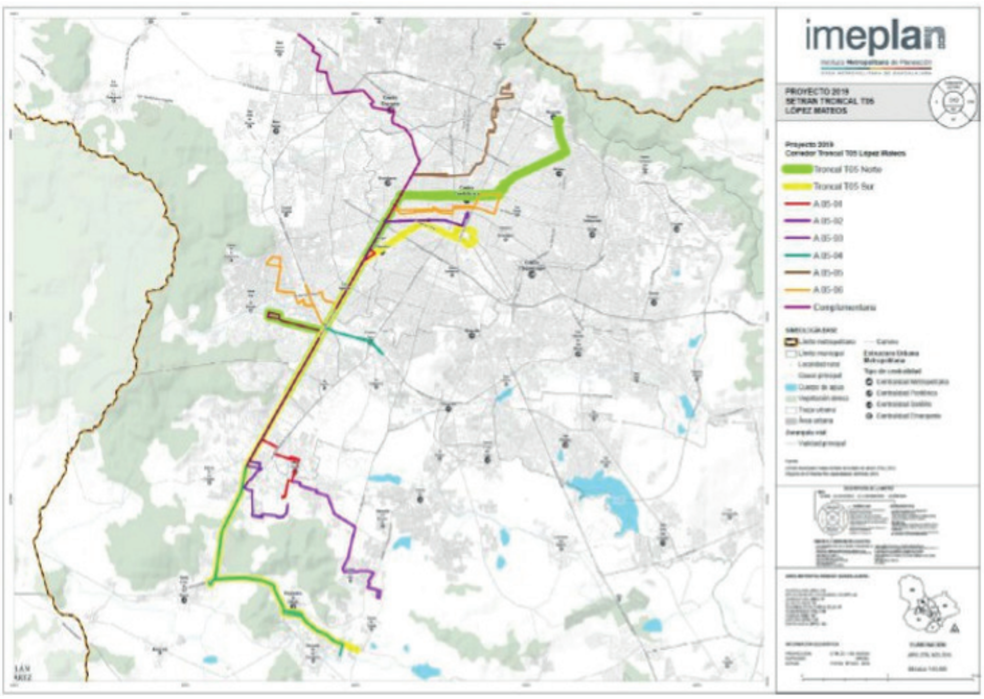
The update includes simplifying the existing network by creating two trunk routes. The first starts in the municipality of Tlajomulco de Zúñiga and uses López Mateos Avenue to reach its destination, the Old Bus Station. The second trunk route originates from the municipality of Guadalajara (Huentitán) and also passes along Av. López Mateos to reach its destination in Santa Ana Tepetitlán (Zapopan). In addition to these trunk routes, there are also four feeder routes in the south (Tlajomulco) and two feeder routes in the north, as well as a complementary route from the north of Zapopan.[13]

https://doi.org/10.56294/tms202359 ISSN: XXXX-XXXX



Source: IMEPLAN[13]

Figure 10. Municipalities involved in Trunk Road 05. López Mateos. 2019 update



Source: IMEPLAN[13]

Figure 11. Trunk route 05. López Mateos. 2019 update

https://doi.org/10.56294/tms202359 ISSN: XXXX-XXXX

Routes of the T05 López Mateos

According to the IMEPLAN[13] update of T05. López Mateos, the following operational data corresponding to the routes were obtained, as shown below:

Trunk Road T05 North (Based on Route 258)

Outbound: 25,68 km

Manuel de J. Aréchiga - Joaquín Amaro - Calz. Juan Pablo II - José María Lozano - Av. Belisario Domínguez - Industria - Independencia - Venustiano Carranza - San Felipe - Andrés Terán - Av. México - Av. Adolfo López Mateos - Camino a Santa Ana Tepetitlán - Aquiles Serdán - Aldama - Galeana - Dr. Mateo de Regil - Javier Mina - Abasolo.

Return: 32,80 km

Guadalupe Victoria - Aquiles Serdán - Camino a Santa Ana Tepetitlán - Av. Adolfo López Mateos - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Av. México - Chapultepec Avenue - Juan Manuel - Federación - Jarauta - Pablo Valdez - Aquiles Serdán - Juan Pablo II Boulevard - Joaquín Amaro - Silvestre Vargas - Ignacio Camarena - Manuel de J. Aréchiga.

Trunk Line T05 South (Based on Route 186)

Outbound: 37,84 km

Camino al Mirador - Prol. Escobedo - Higuera - Vallarta Oriente - Vallarta Poniente

- Av. Pedro Parra Centeno - Carr. a Morelia - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Av. Mariano Otero - Calz. Lázaro Cárdenas - Mariano Otero - Circunvalación Santa Edwiges - Av. Washington - Héroes Ferrocarrileros - Nicolás Bravo - Calz. González Gallo - Analco.

Return: 38,59 km

Av. 5 de Febrero - Av. Constituyentes - Calz. del Águila - Circunvalación Santa Edwiges - Mariano Otero - Calz. Lázaro Cárdenas - Av. Mariano Otero - Ahuízotl - Av. Adolfo López Mateos - Prol. Adolfo López Mateos - Carr. a Morelia - Av. Las Flores - Begonia - Carr. a San Isidro Mazatepec - Av. Pedro Parra Centeno - Prol. Constitución - Constitución Poniente - Constitución Oriente - Higuera - Prol. Escobedo - Camino al Mirador.

To 05-01 (Based on route 182A Balcones)

One way: 18,36 km

Camino a La Loma - Calz. Santa Anita - Camino a La Loma - Prol. 16 de Septiembre

- 16 de Septiembre - Morelos - Allende - Francisco I. Madero - Camino Real de Colima - Ramón Corona - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Av. Plaza del Sol.

Return: 20,74 km

Mariano Otero Avenue - Ahuízotl - Adolfo López Mateos Avenue - Adolfo López Mateos Extension - Road to Morelia - Ramón Corona - Camino Real de Colima - Francisco I. Madero - September 16 - September 16 Extension - Road to La Loma - Santa Anita Boulevard - Road to La Loma.

To 05-02 (Based on route 182 Lomas del Sur)

One way: 28,51 km

From La Providencia - Av. de La Fortuna - Camino Lomas de Tejeda - La Concepción

- Lomas de Luxemburgo - Av. Lomas de Ginebra - Blvr. Lomas del Sur - Carretera Tlajomulco-San Sebastián - Carretera a Tlajomulco - Vicente Guerrero - Emiliano Zapata - 20 de Enero - Zaragoza - Graciano Sánchez - 16 de Septiembre - Prol. 16 de Septiembre - 16 de Septiembre - Morelos - Allende - Francisco I. Madero -

Camino Real de Colima - Ramón Corona - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Av. Plaza del Sol.

Return: 30,94 km

Mariano Otero Avenue - Ahuízotl - Adolfo López Mateos Avenue - Adolfo López Mateos Extension - Carr. a Morelia - Ramón Corona - Camino Real de Colima - Francisco I. Madero - September 16 - Prol. September 16 - September 16 - Graciano Sánchez - Zaragoza - 20 de Enero - Emiliano Zapata - Vicente Guerrero - Carretera a Tlajomulco - Carretera Tlajomulco - San Sebastián - Blvr. Lomas del Sur - Av. Lomas de Ginebra - Lomas de Luxemburgo - Camino Lomas de Tejeda - La Concepción - Av. de La Fortuna - Av. de La Felicidad - Av. del Azar.

To 05-03 (Based on route 183 Lomas de San Agustín)

One way: 28,27 km

Av. de Los Abedules - Loma del Valle - Loma Cerrada Ote. - Loma Escondida Norte

- Loma Real Boulevard - Camino a La Pedrera - Chapala Lake - Cam. a Lomas de San Agustín - Chapala Lake - Lagunitas - Ant. Cam. Real de Colima - Camino Real de Colima - Nicolás R. Casillas - Carr. a Morelia - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Av. Niños Héroes - Av. de Los Arcos - Av. Niños Héroes - 16 de

Septiembre - Colegiales.

Return: 28,24 km

Corona Avenue - Comercio - La Paz Avenue - 16 de Septiembre - Niños Héroes Avenue - Los Arcos Avenue - Niños Héroes Avenue - Adolfo López Mateos Avenue - Prol. Adolfo López Mateos - Carr. a Morelia - Aldama - Matamoros - Camino Real de Colima - Ant. Cam. Real de Colima - Lagunitas - Lake Chapala - Cam. a Lomas de San Agustín - Lake Chapala - Camino a La Pedrera - Blvr. Loma Real - Loma del Valle - Av. de Los Abedules.

To 05-04 (Based on route 186A López Mateos)

One way: 29,70 km

Paseo de La Noria - Camino al Mirador - Prol. Escobedo - Higuera - Vallarta Oriente - Vallarta Poniente - Av. Pedro Parra Centeno - Carr. a Morelia - Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Lateral Periférico - Periférico - Lateral Periférico - Periférico.

Return: 29,43 km

Periférico - Lateral Periférico - Av. Adolfo López Mateos - Prol. Adolfo López Mateos - Carr. a Morelia - Av. Las Flores - Begonia - Carr. a San Isidro Mazatepec - Av. Pedro Parra Centeno - Prol. Constitución - Constitución Poniente - Constitución Oriente - Higuera - Prol. Escobedo - Camino al Mirador - Paseo de La Noria.

To 05-05 (Based on the northern section of route 258A)

Outbound: 13,50 km

Francisco Pastor - Manuel Santa María - Ignacio Solis - Mariano Olivares - María Luisa Martínez - Onofre Gómez Portugal - Pánfilo Natera - Joaquín Mucel - Jerónimo Balleza - Periférico - José María Chávez - Soto y Gama - Ángel Martínez - Monte San Elías - Monte Colli - Av. Normalistas - Fray Junípero Serra - Av. de Los Maestros - Fray Junípero Serra - Jesús García - Av. Adolfo López Mateos.

Return: 13,37 km

Adolfo López Mateos Avenue - José María Vigil - Juan N. Cumplido - Jesús García - Fray Junípero Serra - Los Maestros Avenue - Fray Junípero Serra - Normalistas Avenue - Monte Lisboa - Monte San Elías - Angel Martínez - Eutimio Pinzón - Fernando Franco - Soto y Gama - Juan José de La Garza - Periférico - Jerónimo Balleza - Joaquín Mucel - Pánfilo Natera - Onofre Gómez Portugal - María Luisa Martínez - Mariano Olivares - Juan Carrasco.

A 05-06 (Based on the southern section of Route 258D)

One way: 21,87 km

Prol. Quinceo Volcano - Puerto Pajaritos - Puerto Mexico - Francisco I. Madero - Paseo de La Primavera - Belisario Domínguez - Tepeyac Avenue - Dr. Mateo de Regil - Tlalpan - Colonos Unidos - Playitas - Colonos Unidos - Periférico - Lateral Periférico - Av. Adolfo López Mateos - Av. La Paz - Circ. Agustín Yáñez - Emilio Castelar - Lerdo de Tejada - Juan Ruiz de Alarcón - Lerdo de Tejada - Colonias - Libertad - Calz. del Federalismo - Prisciliano Sánchez - Calz. Independencia - Federación.

Return: 23,34 km

Belisario Domínguez - Ejército - Valentín Gómez Farías - Calz. Independencia - Francisco I. Madero - Calz. del Federalismo - Av. La Paz - Circ. Agustín Yáñez - Adolfo López Mateos Avenue - Galileo Galilei - Mariano Otero Avenue - Periférico - Colonos Unidos - Playitas - Benito Juárez - Tlalpan - Dr. Mateo de Regil - Tepeyac Avenue - Belisario Domínguez - Paseo de La Primavera - Francisco I. Madero - Puerto México - Puerto Pajaritos - Mango - Prol. El Colli - Av. Guadalupe - Priv. Guadalupe.

Complementary (Same route as route 24)

Outbound: 34,74 km

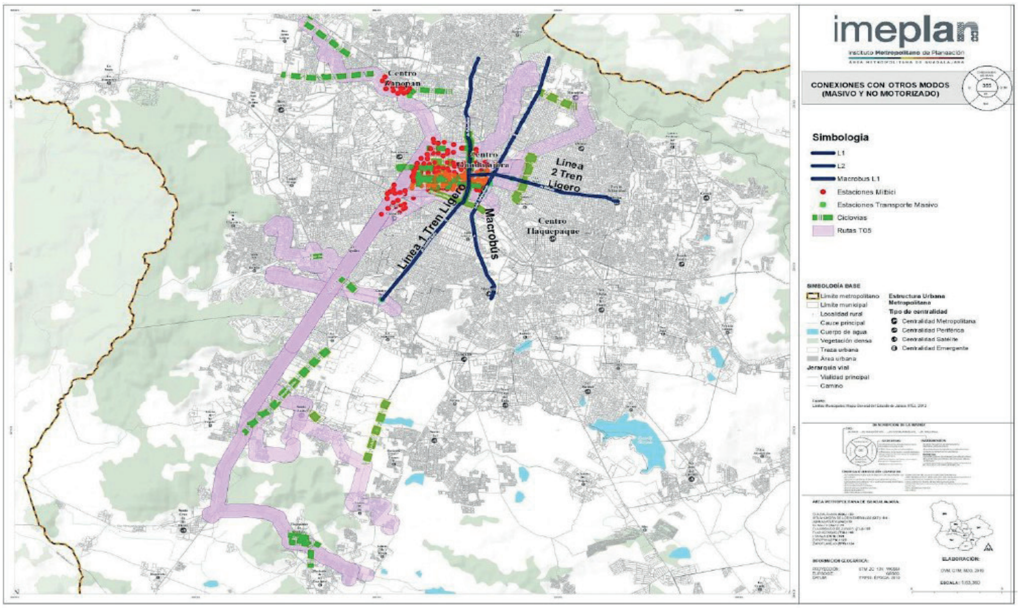
Camino Antiguo a Tesistán - Valle de Tesistán - Av. Valle de Tesistán - Calz. Federalistas - Valle de Las Palmas - Valle de Atemajac - Av. Acueducto - Av. Santa Margarita - Camino a Tesistán - Constitución - Bellavista - Hidalgo - Av. de Los Laureles - Prol. de Las Américas - Av. Adolfo López Mateos - Camino a Santa Ana Tepetitlán - Aquiles Serdán - Aldama - Galeana - Dr. Mateo de Regil - Javier Mina - Abasolo - Guadalupe Victoria - Aquiles Serdán - Camino a Santa Ana Tepetitlán - Av. Adolfo López Mateos - Prol. Adolfo López Mateos.

Return: 27,56 km

Prol. Adolfo López Mateos - Av. Adolfo López Mateos - Prol. de Las Américas - Av. de Los Laureles - Hidalgo - Bellavista - Constitución - Camino a Tesistán - Av. Santa Margarita - Av. Acueducto - Valle de Atemajac - Valle de Las Palmas - Calz. Federalistas - Valle de Tesistán Avenue - Old Road to Tesistán - Air Base Bypass.

Intermodal transport around the T05. López Mateos

The T05. López Mateos has connections with other modes of mass and non-motorized transport. It has intermodality with lines 1 and 2 of the Light Rail, with the Macrobús stations.



Source: IMEPLAN[13]

Figure 12. T05. López Mateos with connections to other modes of mass and non-motorized transport

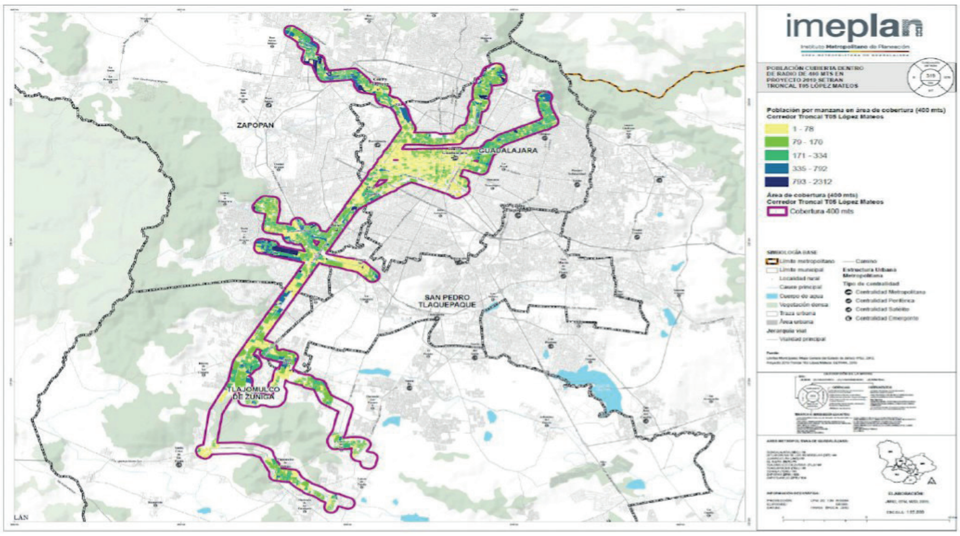
Ruta	Conexiones o Estaciones	Cantidad	Nombre de Estaciones
Troncal T05. Norte	Tren Ligero (L1)	1	Refugio
	Tren Ligero (L1)	1	San Juan de Dios
	Macrobús/Mi Macrocalzada	2	San Juan de Dios, Alameda
	MiBici	63	
	Ciclovías	17	
Troncal T05. Sur	Tren Ligero (L1)	1	Washington
	Macrobús/Mi Macrocalzada	2	Niños Héroes, Agua Azul
	MiBici	12	
	Ciclovías	10	
Alimentador 05-01	MiBici	1	
	Ciclovías	3	
Alimentador 05-02	MiBici	1	
	Ciclovías	4	
Alimentador 05-03	Tren Ligero (L1)	1	Mexicaltzingo
	Macrobús/Mi Macrocalzada	3	La Paz, Niños Héroes, Bicentenario
	MiBici	40	
	Ciclovías	10	
Alimentador 05-04	Tren Ligero (L1)	1	Periférico
	Ciclovías	3	
Alimentador 05-05	Tren Ligero (L1)	1	Mezquitán
	MiBici	24	
	Ciclovías	11	
Alimentador 05-06	Tren Ligero (L1)	2	Mexicaltzingo, Juárez
	Tren Ligero (L2)	4	Juárez, Plaza Universidad, San Juan de Dios, Belisario Domínguez
	Macrobús/Mi Macrocalzada	3	San Juan de Dios, Bicentenario, Alameda
	MiBici	72	
	Ciclovías	13	
Complementaria	MiBici	40	
	Ciclovías	15	

Source: IMEPLAN[13]

Figure 13. Toncal 05. López Mateos with connections to other modes of mass and non-motorized transpor

Demand for service on T05. López Mateos IV.1.1.2.4.1 Population in the T05 corridor. López Mateos

According to IMEPLAN[13] data, within the 400-meter coverage radius of the corridor, the population was calculated per block based on the INEGI population and housing census corridor, the population per block was considered based on the INEGI[12] population and housing census, which shows that the entire corridor has 738 836 inhabitants, with a notable concentration of population on the outskirts of the metropolis, indicating that these areas will generate more trips, contributing to the dynamic in which downtown Guadalajara is the main attraction for travel.

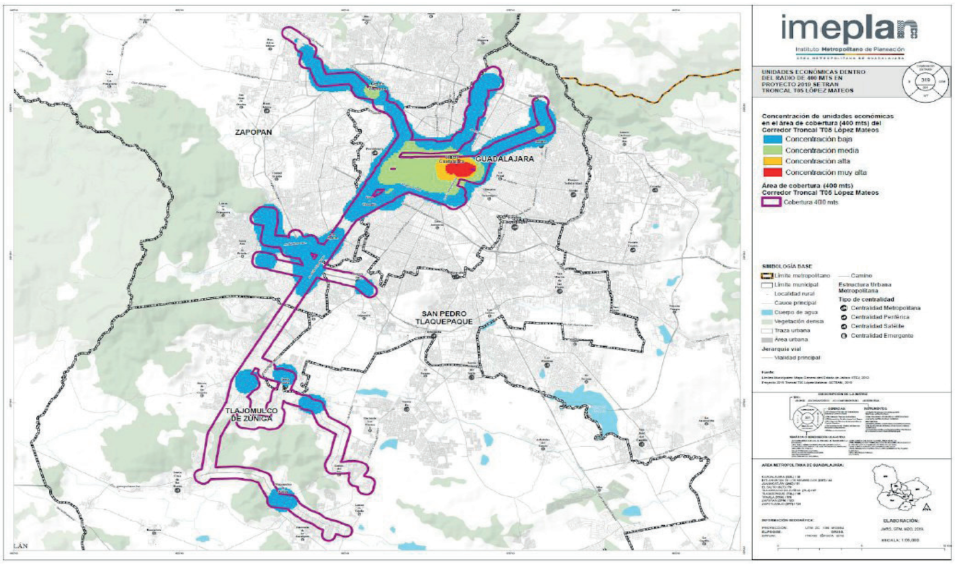


Source: IMEPLAN[13]

Figure 14. Population covered in the T05 corridor. López Mateos

Jobs in the T05 corridor. López Mateos

IMEPLAN[13] estimated the number of jobs within a 400-meter radius of the trunk corridor, arriving at an estimate of 430 744 jobs, with a notable concentration in the center of the municipality of Guadalajara, which contrasts with the distribution of inhabitants.



Source: IMEPLAN[13]

Figure 15. Concentration of jobs in the T05 corridor. López Mateos

Income from the T05. López Mateos

According to data from the Multimodal Travel Demand Study conducted by AU Consultores[15], 2 772 373 trips are made daily on public transportation in the AMG. However, according to data from the Guadalajara Metropolitan Area Planning Institute (IMEPLAN), 4,4 million trips were made daily on public transportation in 2019. This last figure is crucial for understanding the demand for public transportation services.

The total revenue generated by the Troncal 05 López Mateos route is one of the main variables in the public transportation market. To achieve this calculation, demand data generated in the specialized transport planning software model, TransCAD5, corresponding to Troncal 05. López Mateos was used to validate the model for the economic evaluation of Stage 4 of the methodology employed in this thesis. The following algebraic expression was used:

$Y = (Pax * t) + (Ptr * t1)$

Where:
Y: daily revenue per trunk line for service production
Pax: daily passengers per trunk line
t: normal fare
Ptr: daily passengers per trunk line for transfers
$t1$: transfer fare

Figure 16 below shows the calculation of daily revenue (Y) for Trunk Line 05, López Mateos. This calculation was based on the current fare for the route-company model, which is $9,50 MXN for a full fare (t) and $4,50 MXN for a transfer fare (Ptr **).**

Troncal	Pax	Ptr	$Y(Pax * t)$ t=$9.50	$Y(Ptr * t1)$ $t1$=$4.50	Y
TRONCAL 05. López Mateos Norte (258)	33,301	346	$316,360	$1,557	$317,917
TRONCAL 05.02 López Mateos Sur (186)	25,000	302	$237,500	$1,359	$238,859
A 05-01	373	40	$3,544	$180	$3,724
A 05-02	1,277	43	$12,132	$194	$12,325
A 05-03	2,604	261	$24,738	$1,175	$25,913
A 05-04	2,896	0	$27,512	$0.00	$27,512
A 05-05	710	0	$6,745	$0.00	$6,745
A 05-06	7,760	92	$73,720	$414	$74,134
				TOTAL	**$707,128**

Figure 16. Calculated daily revenue from Troncal 05. López Mateos generated by service production
Note: Amounts in MXN/day

The Troncal 05. López Mateos route corridor, consisting of two trunk routes and six feeder routes, generates $707 128 MXN per day. It is important to note that to calculate the daily revenue for the following trunk routes, it is necessary to replicate the aforementioned algebraic expression.

Stage 2: Sizing the behavior of the main operating costs

Operating costs

All expenses related to the operation of the service, i.e., the cost of the factors of production for its provision, are defined as operating costs of public passenger transport. For the purposes of this model, all costs will be standardized in terms of average operating cost per kilometer traveled ($Cmokm$) for a vehicle of type$i$, which will be determined by the following algebraic expression:

$Cmokm, = (Cdkm\ , +Cikm\ , +Gokm\ , +Bdkm\ ,)$

Where:
$Cmokm,$: average operating cost per kilometer traveled by the vehicle i
$Cdkm,$: direct cost per kilometer traveled by the vehicle i
$Cikm,$: indirect cost per kilometer traveled by the vehicle i
$Gokm,$: operating expense per kilometer traveled by the vehicle i
$Bdkm,$: discount ticket per kilometer traveled by the vehicle i

According to the baseline information taken from the "Final ruling for the approval of technical rates for collective passenger transport services for the Routes-Company of the Guadalajara Metropolitan Area and the Integrated System of the City of Puerto Vallarta, issued by the Institute of Mobility and Transport of the State of Jalisco," published in August 2018, they were updated to current prices; that is, to 2019 prices, the main basic inputs necessary for the production of the transport service, which are as follows: fuel (diesel and natural gas), oil, tires, and vehicles, which are presented in figure 17.

Insumo	2018	2019	Variación (%)
Precio de combustible Gas Natural ($/l)	$8.49	$9.99	17.6%
Precio de combustible diésel ($/l)	$19.58	$20.74	5.92%
Vehículo segmento C1 sin rampa	$2,800,000.00	$2,909,226.70	3.90%
Vehículo segmento C1 con rampa	$3,066,350.00	$3,123,224.52	1.85%
Vehículo segmento B sin rampa	$1,830,500.00	$1,905,520.69	4.10%
Vehículo segmento B con rampa	$2,096,850.00	$2,119,518.51	1.08%
Precio aceite ($/l)	$59.58	$61.04	2.45%
Precio de una llanta incluyendo mantenimiento	$4,811.00	$4,944.00	2.76%
Costo del sistema de prepago por vehículo mensual	$8,800.00	$9,134.40	3.80%

Source: Market prices from DINA, Energy Regulatory Commission (CRE), El Salto Natural Gas Distribution Plant S.A. de C.V., LubTrac, Jasman, and Pasajero7. January 11, 2019

Figure 17. Current prices of inputs necessary for the production of public passenger transportation services and growth rate from 2018 to 2019

Direct costs

For this variable, the direct cost per kilometer traveled by the vehicle ($Cdkm$) will be used, and the algebraic expression will be:

$Cdkm, =Cckm , +Cakm , +Clkm ,$

Where:
$Cckm,$: fuel cost per kilometer traveled by the vehicle i
$Cahv,$: oil cost per kilometer traveled by the vehicle i
$Clhv,$: tire cost per kilometer traveled by the vehicle i

Fuel cost

The calculation of fuel cost will depend on the type of vehicle ($Cckm$) and the size of the fleet for each trunk and/or complementary route, the price of fuel, the average fuel consumption, and the average operating speed of the vehicle i. Its algebraic expression will be:

$$Cckm_{,} = \frac{PrC * \overline{V} * Fl}{rdc}$$

Where:
$Cckm,$: fuel cost per kilometer traveled by the vehicle i
PrC: fuel price
V: average travel speed
Fl: fleet of the trunk or complementary route
rdc: fuel efficiency

Fuel price ($/L)

For Compressed Natural Gas (CNG), the value was taken at current 2019 prices, consulted by telephone on January 11 of that year, from the El Salto Natural Gas Distribution Plant, which reported a price (PrC) of $9,99 MXN per liter. For diesel, information published by the Energy Regulatory Commission (CRE) was consulted regarding "National Average Daily Prices and Monthly Prices by State for Gasoline and Diesel" for 2019. The price of diesel fuel (PrC) in the state of Jalisco for January of that year was taken into consideration, which was $20,74 MXN per liter.

Fuel efficiency (km/lt)

To calculate fuel efficiency (rdc), in the case of vehicles that use CNG and based on the technical specifications provided by the supplier consulted during the data collection and update, the figure is 1,8 km/lt, and in the case of vehicles that use diesel, the figure is 2,1 km/lt.

Oil cost

This direct cost represents oil consumption by vehicle type ($Cakm$) per fleet on the main or complementary route. Its algebraic expression is as follows:

$$\frac{KmT}{KmCa}] \frac{PrCa * l}{KmT} ` Fl$$

Where:
$Cakm_i$: oil cost per kilometer traveled by vehicle i
$PrAc$: price of oil
KmT: kilometers traveled per year per vehicle
Fl: main or complementary route fleet
$KmCa$: kilometers of service between oil changes
l: Crankcase capacity

Oil price

This information was obtained from LubTrac by telephone. The price per liter of oil ($PrAc$) provided was $61,04 MXN, considering large-scale purchases, i.e., in drums with a capacity of 208 liters.

Crankcase capacity

The crankcase capacity (l) according to the technical specifications provided by the vehicle supplier is 24 liters.

Hours between oil changes

According to the technical data sheets provided by the vehicle suppliers, consulted for the update, oil changes ($KmCa$) should be performed every 937 hours of service.

Cost per tire

To calculate this direct cost in the production of the public transport service, the following algebraic expression will be used:

$$Clkm_i = \frac{PrLl * nLl * Fl}{VeLlkm}$$

Where:
$Clkm_i$: Cost of tires per kilometer traveled by vehicle i
$PrLl$: Unit price of a tire including maintenance
nLl: Number of tires
Fl: Fleet of the trunk or complementary route
$VeLlkm$: Economic life of tires in kilometers traveled

Unit price of tires, including maintenance

According to information provided by Pasajero7 and Jasman, the unit price of a 11R/22,5 tire ($PrLl$), including maintenance, is $4944,00 MXN.

Fleet tire price for trunk or complementary routes

This direct cost is the product of the number of tires (nLl) multiplied by the number of vehicles on the trunk or complementary route (Fl). It is important to note that this cost includes nine tires per unit (six tires integrated into the vehicle, one spare, and two additional front tires for rapid wear), i.e., one and a half sets per unit.

Economic life of tires in kilometers

The useful life of a complete set of tires ($VeLlKm$) is 120 000 kilometers. It should be noted that one and a half sets of tires per vehicle were quoted.

Indirect costs

For this variable, the concept of indirect cost per hour of vehicle use was used ($Cikm$), and the following algebraic expression was used:

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$$Cikm_i = Cafkm_i + Cskm_i + Cmkm_i$$

Where:
$Cafkm_i$: cost per kilometer traveled by the vehicle under a financial lease i
$Cskm_i$: insurance cost per kilometer traveled by the vehicle i
$Cmkm_i$: maintenance cost per kilometer traveled by the vehicle i

Fleet and vehicle acquisition value

In this category of the cost structure, it is important to have an updated record of both the acquisition value of the vehicle by type i and the value of the fleet for the main and/or complementary route, which will be represented by the following variables: Prv, and $PrFl$, respectively. For this purpose, the acquisition value of the vehicles was quoted by the company DINA on January 11, 2019 (Table 9). The price of the vehicle according to type is as follows: Segment “C” vehicle without ramp, $2 909 226,70 MXN; Segment “C” vehicle with ramp, $3 123 224,52 MXN; “B” segment vehicle without ramp, $1 905 520,69 MXN; and “B” segment vehicle with ramp, $2 119 518,51 MXN. The following algebraic expression was used to calculate the value of the fleet:

$$PrFl = Prv_i * Fl$$

Where:
$PrFl$: Acquisition value of the fleet
Prv_i: Acquisition value of the vehicle i
Fl: Fleet on the main or complementary route

Cost per financial lease

The cost of the financial lease per kilometer traveled by vehicle type ($Cafkm$) will be represented by the following algebraic expression:

$$Cafkm_i = \frac{\frac{(K * n)}{z - 12}(z - n)[k(r)(z - n)]\frac{K(1 - n)}{z} - (PrFl * vr)}{(z * KmS)365}$$

Where:
r: annual interest rate
K: total loan payment
k: partial loan payment
n: loan term
z: economic life of the vehicle in years
vr: percentage of residual value
va: current value
Fl: main or complementary route fleet
$PrFl$: acquisition value of the rolling stock
Prv_i: acquisition value of the vehicle i
KmS_i: kilometers traveled in service per day per vehicle i

This indirect cost includes the annual interest rate (r) provided by DINA, which is 14,5 %. The total loan payment (K) represents the sum of all payments made at the end of the loan term (n), which, according to the information provided by the DINA group’s financial institution, Mercader Financial, is five years. Likewise, based on the information provided by the aforementioned company, the percentage of the vehicle’s residual value (vr) at the end of its useful life is 10 % for vehicles powered by Compressed Natural Gas (CNG) and 15 % for vehicles powered by diesel.

To determine the economic life of the unit in years (z), the provisions of the General Technical Standard specifying the characteristics that vehicles must have for urban, suburban, metropolitan, and suburban public passenger transport services and special characteristics were taken into account. In the case of the State of Jalisco, it is 10 years.

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Cost per insurance service

The calculation of the cost of insurance per kilometer traveled by the vehicle$i$ per fleet ($Cskm$) considers the insurance premium factor (sg), which is established in Article 150 of the Regulations of the Mobility and Transportation Law of the State of Jalisco for vehicles used for public transportation services, which is 3 % of the total cost of the unit according to the mutual insurance company consulted (Quálitas) for the model. The following algebraic expression will be used for the calculation:

$$Cskm_{,} = \frac{PrFl * sg}{Km * 365}$$

Where:
$Cskm,$: insurance cost per kilometer traveled by vehicle i
$PrFl$: acquisition value of the rolling stock
sg: insurance premium factor
Km: kilometers traveled per year per vehicle

Maintenance cost

To calculate the maintenance cost per vehicle type$i$ per fleet ($Cmkm$), the annual maintenance percentage will be considered and the following algebraic expression will be used:

$$Cmkm_{,} = \frac{fm * PrFl}{Km * 365}$$

Where:
$Cmkm,$: insurance cost per kilometer traveled by vehicle i
fm: annual maintenance percentage
$PrFl$: acquisition value of the rolling stock
HrT: hours worked per year per vehicle

For this percentage, suppliers and carriers were consulted by telephone, and maintenance costs are estimated at 10 % of the total cost of the unit.

Operating expenses

To calculate the operating expenses per hour for the vehicle type$i$ ($Gokm$), all expenses necessary to operate each trunk line were considered, and the following algebraic expression was used:

$$Gokm_{,} = Cpkm_{,} + CPrkm_{,} + Gakm_{,} + Gikm_{,}$$

Where:
$Gokm,$: operating expense per kilometer traveled by the vehicle i
$Cpkm,$: personnel cost per kilometer traveled by the vehicle i
$CPrkm,$: cost per service per kilometer traveled by the vehicle i
$Gakm,$: administrative expenses per kilometer traveled by the vehicle i
$Gikm,$: infrastructure expenses per kilometer traveled by the vehicle i

Personnel cost per kilometer and fleet

To estimate and calculate the cost of the personnel required to operate a trunk route under the business model ($Cpkm$), i.e., organized by administrative, operational, and maintenance areas, the following items were calculated: monthly payroll cost (nm), the average number of days per month7 (fdm), and the number of kilometers traveled per day (Kmd). Given the above, the following algebraic expression will be used:

$$Cpkm_{,} = \frac{nm}{(fdm * Kmd)}$$

Where:
$Cpkm,$: personnel cost per kilometer traveled by the type of vehicle i
nm: monthly payroll

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fdm: average monthly days factor
Kmd: kilometers traveled per day per vehicle type i

To calculate the monthly payroll (nm), a standard organizational chart was used for all trunk lines, consisting of the following structure: Assembly, General Management, Legal Department, Administrative Department, Operations Department, Maintenance Department, and Fuel Department. The following algebraic expression will be used for the calculation:

$$nm = \frac{Cnm * Fl * cnv}{Pv}$$

Where:
nm: monthly payroll
Cnm: monthly payroll cost
Fl: fleet of the trunk or complementary route
$cnv,$: nominal capacity for the vehicle i
$Pv,$: proportion of vehicles by type$i$ tion of the entire General Transportation Program

To calculate the average number of days per month (fdm), the factor established in Article 1429 of the Income Tax Law (ISR) was used, i.e., 30,42 days, and for the kilometers traveled per day (Kmd), the kilometers traveled per vehicle per day were considered, plus the kilometers traveled empty per vehicle.

Cost of benefits per kilometer

To calculate this item ($CPrhv$), official parameters from the Mexican Social Security Institute (IMSS), the National Workers' Housing Fund Institute (INFONAVIT), the 2 % state payroll tax, and the Retirement Savings System (SAR) per kilometer traveled per vehicle. Based on the above, it is estimated that this parameter represents 30 % of the operating expense of a route-company. The following algebraic expression was used to calculate this expenditure:

$$CPrkm_{,} = \frac{(nm * Ppr)}{(fdm) * (Kmd)}$$

Where:
$CPrkm,$: cost of benefits per kilometer traveled by the type of vehicle i
nm: monthly payroll
fdm: average number of days per month
Ppr: percentage of benefits
Kmd: kilometers traveled per day per vehicle type i

Administrative expenses

This administrative expense ($Gakm$) consists of the expenditure resulting from the operation of a prepaid system and considers an outlay per vehicle and fleet. The following algebraic expression was used for this item:

$$Gakm_{,} = \frac{(Fl * CsirV)}{fdm} / Kmd$$

Where:
$Gakm,$: administrative expenses per hour of the vehicle type i
Fl: fleet on the main or complementary route
fdm: average number of days per month
$CsirV$: cost of the interoperable collection system per vehicle type i
kmd: kilometers traveled per day per vehicle type i

It should be noted that, given that the supplier's data was not available, the cost of the interoperable collection system per vehicle ($CsirV$) was calculated based on the 2018 cost established in IMTJ-532/2018/DND issued by the Technical Committee for Fare Validation, plus the 2019 inflation increase, resulting in $9134 MXN per vehicle.

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Infrastructure expenses

The expenses generated by the operation of the facilities on each trunk or complementary route ($Gikm$) were calculated using the following algebraic expression:

$$Gikm_{,} = \frac{[Pas^{(1+ftr)}(t-tr)][>\alpha+\beta?]}{HrTd}$$

Where:
$Gikm,$: infrastructure expenses per kilometer traveled by vehicle type i
Pas: daily passengers per vehicle type i
t: fare
tr: amount of discounted tickets per kilometer traveled by vehicle type i
ftr: transfer factor per trip
α: percentage of facility costs relative to trunk line revenues
β: percentage of control center cost relative to trunk line revenue
Kmd: kilometers traveled per day per vehicle type i

Discount tickets

In this section, it is important to note that since there is no official information provided by the transport union or by the company that generates the discount ticket ($Bdkm$) known as "Mi Pasaje," the percentage established in Ruling IMTJ-532/2018/DND issued by the Technical Committee for Fare Validation in August 2018 was used, to what was known as Bienevale and Transvale. That said, the percentage of discounted tickets (σ) is 9,30 % per vehicle. To calculate the number of discount tickets and their cost per vehicle and per fleet, the following algebraic expression was used:

$$Bdkm_{,} = \frac{\sigma * Pas^{(9@A\#7)}}{Kmd}$$

Where:
$Bdkm,$: discount tickets per kilometer traveled by vehicle type i
σ: percentage of discounted tickets
Pas: daily passengers per vehicle type i
ftr: transfer factor per trip
Kmd: kilometers traveled per day per vehicle type i

In conclusion, the cost structure of public passenger transport operating in the AMG is defined as follows: Direct costs (fuel, oil, and tires); Indirect costs (bus price, financial leasing, interest rate, term, redemption value, economic life, and maintenance); Operating expenses (personnel costs, benefit costs, administrative expenses, and infrastructure expenses) and costs generated by discount tickets. For the social fare, the 2015 Intercensal Survey by INEGI was considered, as well as the 2016 User Satisfaction Survey for the Guadalajara Metropolitan Area, conducted by the Jalisco State Institute of Mobility and Transportation, and the expenditure categories of the National Consumer Price Index (INPC) for 2019.

Based on the above, it was possible to determine the percentage of daily and monthly expenditure on public transport by area and income level. In addition, the data obtained was used to consider other variables such as the percentage of users without a car, public transport users, and a possible determination of the social fare for the "Mi Transporte" Integrated Transport Model. In short, the conditions required for obtaining a social transport fare serve as a reference point for promoting new public transport policies with social pricing, which is understood as measures to combat social exclusion.

Stage 3: Explanation of the fare scheme

The analysis of the current fare presents a more adverse picture, as total operating costs have increased substantially in the provision of the service. The state government must therefore define the rules of the game regarding public transport fares. With these rules, entrepreneurs can measure their capacity and jointly determine a real public policy, where the costs and benefits for each member are known.

However, Jalisco continues to make unilateral decisions, and the government does not usually accurately assess the consequences of continuing with a punitive or social fare policy without providing subsidies. Two types of subsidies have been used for public transport in Jalisco: direct and indirect. The first is when the government pays the subsidy percentage directly through its expenditure policy, and the second is when the cost of differentiated tickets is distributed among the total number of tickets sold. In summary, the following types of fares can be defined:

a) Technical fare: this is when the price of the service covers all expenses and projected profits. In this way, if the government decides to implement a technical fare that allows entrepreneurs to have a healthy and efficient economy that depends solely on the payment for the service, it would then be possible to eliminate any subsidy.

b) Zero-profit tariff: this is when the state provides the transport service, and only the costs of providing the service are covered. In this sense, if the government decides to implement a “zero-profit” tariff for government agencies whose objective is not to obtain economic benefits, private companies (service providers) will receive the profit through a subsidy.

c) Social fare: this is when the State sets the fare price below operating costs. Here, suppose the government decides to implement a so-called social fare for all service providers. In that case, it should then include a significant amount for the payment of subsidies in its expenditure policy.

d) Weighted tariff: this is calculated by weighting the costs of different types of vehicles to facilitate estimation.

e) Punitive fare: this is when the state reduces the price of the service to encourage transport operators to improve the service they offer.

On the other hand, one way to increase the modal share of public transport is to introduce even more competitive pricing compared to private car use. In this sense, having a socially fair fare means that users perceive that they are receiving favorable treatment.

Regular users behave in a way that benefits society as a whole, since public transport reduces the social, economic, environmental, energy, and health impacts of the massive and abusive use of private vehicles.

According to data from the SETRAN State Transport Registry there are currently approximately 5179 public transport units in the AMG, with a current fare of MXN 9,50. Additionally, in November 2023, the Constitutional Governor of Jalisco, Enrique Alfaro Ramírez, announced a subsidy of MXN 500 000 000,00, equivalent to approximately 41 cents per passenger.

Stage 4: Development of the econometric and economic evaluation model

Application of the model to the cost structure

To formulate the econometric model in Stata 18 and apply it to the cost structure, the following items were operationalized and updated for 2019: average operating costs per vehicle, direct costs per hour per vehicle, indirect costs per hour per vehicle, operating expenses, and discount ticket costs.

To develop and apply this model, all costs were standardized in terms of average operating cost per kilometer traveled (Cmokm) for vehicle type I, which was determined by the following equation:

$$Cmokm_i = \beta_i + \beta_9 Cdkm_i + \beta_B Cikm_i + \beta_C Gokm_i + \beta_D Bdkm_i + u_i$$

Where:

$Cmokm_i$: average operating cost per kilometer traveled by the vehicle i

$Cdkm_i$: direct cost per kilometer traveled by the vehicle i

$Cikm_i$: indirect cost per kilometer traveled by the vehicle i

$Gokm_i$: operating expense per kilometer traveled by the vehicle i

$Bdkm_i$: discount ticket per kilometer traveled by the vehicle i

u_i: vehicle disturbance variable or error i

β: estimation coefficients i

```
. reg Cmokm Cdkm
```

Source	SS	df	MS
Model	32.9052058	1	32.9052058
Residual	208.888065	82	2.54741543
Total	241.793271	83	2.91317194

Number of obs	=	84
F(1, 82)	=	12.92
Prob > F	=	0.0006
R-squared	=	0.1361
Adj R-squared	=	0.1256
Root MSE	=	1.5961

Cmokm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Cdkm	.4474966	.1245109	3.59	0.001	.1998048	.6951884
_cons	18.47278	1.047483	17.64	0.000	16.389	20.55656

Source: PGT, 2019

Figure 18. Model estimation. Average costs vs. direct costs

Using the Ordinary Least Squares (OLS) method, the aforementioned model was applied with operating data from the General Transportation Program trunk lines, as can be seen in figures 18 to 21.

. reg Cmokm Cikm

Source	SS	df	MS
Model	1.78756601	1	1.78756601
Residual	240.005705	82	2.92689884
Total	241.793271	83	2.91317194

Number of obs	=	84
F(1, 82)	=	0.61
Prob > F	=	0.4368
R-squared	=	0.0074
Adj R-squared	=	-0.0047
Root MSE	=	1.7108

Cmokm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Cikm	.1937865	.2479684	0.78	0.437	-.2995017	.6870747
_cons	21.46136	.9446942	22.72	0.000	19.58206	23.34066

Source: PGT, 2019

Figure 19. Model estimation. Average costs vs. indirect costs

. reg Cmokm Gokm

Source	SS	df	MS
Model	206.055006	1	206.055006
Residual	35.7382651	82	.435832502
Total	241.793271	83	2.91317194

Number of obs	=	84
F(1, 82)	=	472.78
Prob > F	=	0.0000
R-squared	=	0.8522
Adj R-squared	=	0.8504
Root MSE	=	.66018

Cmokm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Gokm	1.534779	.0705853	21.74	0.000	1.394362	1.675195
_cons	8.093526	.6520684	12.41	0.000	6.796354	9.390698

Source: PGT, 2019

Figure 20. Model estimate. Average costs vs. operating expenses

. reg Cmokm Bdkm

Source	SS	df	MS
Model	55.3901387	1	55.3901387
Residual	186.403132	82	2.27320893
Total	241.793271	83	2.91317194

Number of obs	=	84
F(1, 82)	=	24.37
Prob > F	=	0.0000
R-squared	=	0.2291
Adj R-squared	=	0.2197
Root MSE	=	1.5077

Cmokm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Bdkm	2.235277	.4528296	4.94	0.000	1.334455	3.1361
_cons	20.00957	.4704222	42.54	0.000	19.07375	20.94539

Source: PGT, 2019

Figure 21. Model estimate. Average costs vs. discount ticket

Tarifa técnica para vehículos GNC					
Tipo de costo	Insumo	Pesos/Km	Tipo de costo	Coeficiente	Coeficiente por insumo
CDKm	Gas Natural Comprimido	5.20	6.08	28%	24%
	Aceite	0.21			1%
	Llantas	0.68			3%
CIKm	Arrendamiento financiero	0.47	5.58	26%	2%
	Seguro	0.70			3%
	Mantenimiento	4.41			20%
GOKm	Costo de personal	5.87	9.22	42%	27%
	Costo prestaciones	1.17			5%
	Gastos administrativos	1.04			5%
	Gastos de infraestructura	1.14			5%
BdKm	Boletos con descuento	0.84	0.84	4%	4%
Tarifa técnica			$ 21.73	100%	100%

Source: PGT, 2019

Figure 22. Calculation of AMG public transport operating costs for the technical fare for CNG buses. 2019

Tarifa técnica para vehículos de diésel					
Tipo de costo	Insumo	Pesos/Km	Tipo de costo	Coeficiente	Coeficiente por insumo
CdKm	Diésel	8.30	9.18	39%	36%
	Aceite	0.21			1%
	Llantas	0.68			3%
CiKm	Arrendamiento financiero	0.31	4.41	19%	1%
	Seguro	0.70			3%
	Mantenimiento	3.40			15%
GoKm	Costo de personal	5.44	8.79	38%	23%
	Costo prestaciones	1.09			5%
	Gastos administrativos	0.96			4%
	Gastos de infraestructura	1.30			6%
BdKm	Boletos con descuento	0.96	0.96	4%	4%
Tarifa técnica			$ 23.34	100%	100%

Source: PGT, 2019

Figure 23. Calculation of AMG public transport operating costs for the technical fare for diesel buses. 2019

The costs shown in figures 24, 25, and 26 consider the entire public transport fleet operating in the AMG, where the technical fare is the price that should be applied to all transport companies and for the provision of services. However, the fare is measured in monetary units per unit of transport provided, in this case: $/passenger; that is, $9,50 (about half a US dollar).

Tarifa técnica para unidades articuladas BRT (Macrobús)					
Tipo de costo	Insumo	Pesos/Km	Tipo de costo	Coeficiente	Coef. por insumo
CdKm	DUBA	17.81	19.06	44%	41%
	Aceite	0.35			1%
	Llantas	0.90			2%
CiKm	Arrendamiento financiero	1.22	12.04	28%	3%
	Seguro	2.21			5%
	Mantenimiento	8.61			20%
GoKm	Costo de personal	5.31	10.02	23%	12%
	Costo prestaciones	1.06			2%
	Gastos administrativos	0.94			2%
	Gastos de infraestructura	2.71			6%
BdKm	Boletos con descuento	2	2	5%	5%
Tarifa técnica			$ 43.12	100%	100%

Source: PGT, 2019

Figure 24. Calculation of AMG public transport operating costs for the technical fare for articulated BRT units. 2019

In this case, AMG transport operators have a profit margin of approximately 15 %, which indicates that the technical fare and passenger levels cover operating costs.

For the social tariff, Mexican families allocate a significant portion of their income (13,4 %) to transportation services, which ranks third among the categories with the highest weight (figure 25).

Categoría/Consumidor	Ponderación en el INPC
Alimentos, bebidas y tabaco	22.70%
Ropa, calzado y accesorios	5.60%
Vivienda	26.40%
Muebles, aparatos y accesorios domésticos	4.90%
Salud y cuidado personal	8.60%
Transporte	**13.40%**
Educación y esparcimiento	11.50%
Otros servicios	6.90%
Total	100.00%

Source: INPC, 2019, INEGI

Figure 25. Percentage distribution of income for consumption

Grupo	% de usuarios sin automóvil	Usuarios totales del TP	Gasto diario promedio en transporte	Gasto promedio mensual en transporte	Ingreso promedio por rango económico	% gasto mensual / ingreso mensual	Relación INPC	Tarifa social
Sin ingresos	19.9	316,902	21.43	535.75				
De 0 a 2 vsm	40.4	643,359	22.60	565.00	$4,167.42	13.6%	0.99	$6.92
2 a 5 vsm	35.7	568,513	23.98	599.50	$6,826.19	8.8%	1.53	$10.68
Más de 5 vsm	4.0	63,699	27.42	685.50	$15,826.71	4.3%	3.09	$21.66
Totales	**100**	**1,592,473**						

Source: INEGI[80] 2015 Intercensal Survey and the 2016 AMG User Satisfaction Survey

Figure 26. Economic analysis of social fares by economic bracket

According to the 2015 INEGI Intercensal Survey, 13,6 % of the AMG population that uses public transportation earns between 0 and 5 times the minimum wage (vsm); 8,8 % earn between 2 and 5 vsm, and 4,3 % earn 5 vsm or more per zone. Based on these data and those from the 2016 User Satisfaction Survey for the AMG, the following social fare prices by economic range are obtained (figure 26).

The data in the table above show that the population belonging to the no-income group represents 19,9 % of the AMG population and does not own a car, i.e., about 875 000 people, of whom only 316 902 are public transport users. On average, they spend \$21,43/day or \$535,72/month. Based on the above, it can be inferred that people belonging to this group receive support from a family member, such as the head of the household, and can be placed in any segment of the AMG population.

For the group of users who earn between 0 and 2 times the minimum wage, they spend \$565,00 per month on average for transportation services, which is 13,6 % of their income and represents 40,4 % of people who do not own a car (around 643 359 public transportation users). This group is eligible to pay a social fare of \$6,92. On the other hand, the group that earns between 2 and 5 times the minimum wage can pay a social fare of around \$10,68, and those in the group that earn more than 5 times the minimum wage can afford a social fare of \$21,66.

In this context, someone earning the minimum wage (\$123,22/day) receives \$3696. If that person makes four trips a day (Monday through Saturday) on transportation that costs \$9,50, then they spend \$912 per month. Furthermore, if this person belongs to a family of four who also make these trips, the household would spend \$3648. If the fare rises to 10 pesos, that person would spend \$960/month. From this, a family of four would spend \$3840. This situation becomes unaffordable when considering that 64 % of the population in the state earns less than three minimum wages.

According to INEGI[12], 8,6 % of the population of Jalisco earns less than one minimum wage; about 25 % earn between one and two minimum wages; 30 % earn between two and three; 17,5 % earn between three and five; 6,7 % earn more than five; those with no income account for 4,1 %; and those not specified account for 8 %. In total, those who earn less than three minimum wages represent 64 % of the employed population.

Economic evaluation of public transportation

This section describes the transport supply, demand, and the evaluation method that takes into account the value of the income generated by the production of transport services over time, including the Internal Rate of Return (IRR), Net Present Value (NPV), and the Internal Rate of Return (IRR). This stage is critical, as it ultimately allows for the implementation of trunk routes to be decided; therefore, the investment decision almost always falls on the economic evaluation.

Additionally, given that the initial investment may come from various sources, including individuals or legal entities, it will incur an associated cost. Therefore, a Minimum Acceptable Rate of Return (MARR) will be established to determine the minimum rate of return on the investment.

Furthermore, this assessment was conducted with a 10-year assessment horizon, and the daily income generated in Section "IV.1.1.2.4.3 Income from T05. López Mateos" was annualized to calculate the Net Cash Flows (NCF). This annual operating income will be expressed with the variable Yn.

Minimum acceptable rate of return (MARR)

It should be noted that for the evaluation of trunk routes, since they do not involve public investment, the discount rate of the Ministry of Finance and Public Credit (SHCP) was not used, and the MAR was chosen instead.

The following algebraic expression was used to calculate the minimum acceptable rate of return:

$$TMAR = ri + f$$

Where:
$TMAR$: minimum Acceptable Rate of Return
ri: risk rate
f: inflation rate

In this regard, to define the value of the risk rate, the criteria of the "Industry Risk Methodology" carried out by Standard & Poors in 2018 was used as a reference. The risk classification for this economic evaluation model is as follows:

Determinación de la evaluación global del riesgo de la industria del transporte		
Escala de riesgo	Riesgo bajo	DE 1 A 2%
	Riesgo medio	DE 2 A 4%
	Riesgo alto	DE 4 A 6%
	Riesgo muy alto	MÀS DE 6%

Source: Standard et al.[114]

Figure 27. Risk classification scale for the transportation industry

For the purposes of evaluating trunk routes and conditions for the transportation industry as indicated in the aforementioned methodology, a high risk rate of 6,20 % was applied. For the data corresponding to the estimated annual inflation rate (f) for 2019, the Bank of Mexico (BANXICO) was consulted, projecting a rate of 3,8 %.

Therefore, the MAR used for the evaluation of trunk routes is as follows:

Parámetro	Tasa de riesgo (ri)	Tasa de inflación (f)	$TMAR$
Valor	6.20%	3.8%	**10%**

Source: BANXICO[25] and Standard et al.[114]

Figure 28. Minimum Acceptable Rate of Return for the evaluation of the PGT

Net present value (NPV)

The monetary figures obtained from the calculation of the income from the production of the trunk route service under study must now be transformed into an economic profitability index. The figures used to calculate these profitability indices are the initial investment, net cash flows, and the bus lease data provided by the financial company "Mercader Financial" of the DINA group.

The Net Present Value (VPN) indicates the change in the value of the money invested in the trunk routes over time, i.e., how profits (if any) are obtained over the years. To begin the calculation, the Net Cash Flows (FNE)10 were first quantified over a 10-year time horizon, as mentioned above. It should be noted that the higher the net cash flows, the better the economic profitability. Figure 29 shows the annual operating cost data expressed in the letters ($COpN$) for trunk route 05, López Mateos.

Next, to calculate the annual income (Yn) from the provision of the service on the Troncal 05. López Mateos route, the daily income levels were multiplied by the number of days in the year, as shown in figure 30.

CONCEPTO	Escenario Diésel $COpN$ ($ anuales)	Escenario GNC $COpN$ ($ anuales)
Costo por arrendamiento financiero	21,008,365.61	28,675,424.89
Seguros	8,003,186.90	10,923,971.39
Mantenimiento	26,677,289.66	36,413,237.96
Combustible	159,331,859.99	108,770,531.94
Aceite	1,238,336.79	1,238,336.79
Llantas	9,466,305.88	9,466,305.88
Costo de personal	1,839,670.49	2,550,876.44
Costo de prestaciones	551,901.15	765,262.93
Gastos administrativos	15,345,623.83	15,345,623.83
Gastos de infraestructura	707,365.79	707,365.79
Costo por boletos de descuento	549,858.06	549,858.06
COSTO TOTAL	**244,719,764.13**	**215,406,795.89**

Source: PGT, 2019

Figure 29. Annual operating costs (COpN) for Troncal 05. López Mateos

Note: Diesel scenario: Consists of two trunk lines (97 vehicles) and six feeders (43 vehicles) with a total fleet (Fl) of 140 diesel-powered units. CNG scenario: Consists of two trunk lines (97 CNG vehicles) and six feeders (43 diesel vehicles) with a total fleet (Fl) of 140 units.

Troncal	Pax	Ptr	$Y(Pax * t)$ t=$9.50	$Y(Ptr * t1)$ t1=$4.50	Y ($ día)	Yn ($ año)
TRONCAL 05. López Mateos Norte (258)	33,301	346	$ 316,360	$ 1,557	$ 317,917	$116,039,523
TRONCAL 05.02 López Mateos Sur (186)	25,000	302	$ 237,500	$ 1,359	$ 238,859	$87,183,535
A 05-01	373	40	$ 3,544	$ 180	$ 3,724	$1,359,078
A 05-02	1,277	43	$ 12,132	$ 194	$ 12,325	$4,498,625
A 05-03	2,604	261	$ 24,738	$ 1,175	$ 25,913	$9,458,063
A 05-04	2,896	0	$ 27,512	$ -	$ 27,512	$10,041,880
A 05-05	710	0	$ 6,745	$ -	$ 6,745	$2,461,925
A 05-06	7,760	92	$ 73,720	$ 414	$ 74,134	$27,058,910
				TOTAL	**$ 707,128**	**$258,101,538**

Source: PGT, 2019

Figure 30. Annual revenue from Trunk Line 05. López Mateos generated by service production

Note: Amounts in $mxn/year.

Next, once the annual operating costs ($COpN$) for both diesel and CNG-powered vehicles were obtained, as well as the annual revenue generated from service production, the net present values (FNE) were calculated for a 10-year horizon. These flows are represented by the following algebraic expression:

$$FNE = Yn - COpN$$

Where:
FNE: net Cash Flows
Yn: annual revenue generated by service production
$COpN$: annual Operating Costs

It should be noted that income levels from year 2 onwards, given that the data provided by the TransCAD model are from 2014, will remain constant 11 until year 10, as shown in figure 31.

Año	Costos de operación anuales ($COpN$) $	Ingresos anuales (Yn) $	Flujos Netos de Efectivo (FNE) $
0*	-244,719,764	-	-
1	245,731,284	258,101,538	12,370,253
2	245,731,284	258,101,538	12,370,253
3	266,739,650	258,101,538	-8,638,112
4	267,751,170	258,101,538	-9,649,632
5	285,758,340	258,101,538	-27,656,803
6	264,605,472	258,101,538	-6,503,934
7	264,605,472	258,101,538	-6,503,934
8	264,605,472	258,101,538	-6,503,934
9	242,585,586	258,101,538	15,515,951
10	242,585,586	258,101,538	15,515,951

Source: PGT, 2019

Figure 31. Net Cash Flows for Trunk Line 05. López Mateos, diesel

Note: *Period "0" corresponds to the initial investment required to start up the trunk line project with the entire fleet of diesel vehicles.

The figure above shows that the Trunk Line 05 project with diesel vehicles, from period 3 to 8, shows negative cash flows. Next, the cash flows for the same trunk route are shown for CNG vehicles on the trunk lines and diesel vehicles on the feeders.

Año	Costos de operación anuales ($COpN$) $	Ingresos anuales (Yn) $	Flujos Netos de Efectivo (FNE) $
0*	-215,406,796		
1	216,787,473	258,101,538	41,314,065
2	216,787,473	258,101,538	41,314,065
3	245,462,898	258,101,538	12,638,640
4	246,843,575	258,101,538	11,257,963
5	271,422,510	258,101,538	-13,320,973
6	242,549,846	258,101,538	15,551,692
7	242,549,846	258,101,538	15,551,692
8	242,549,846	258,101,538	15,551,692
9	212,493,744	258,101,538	45,607,794
10	212,493,744	258,101,538	45,607,794

Source: PGT, 2019

Figure 32. Net Cash Flows for Trunk Line 05. López Mateos, CNG and diesel for feeders

Note: *Period "0" corresponds to the initial investment required to start up the trunk line project with CNG and diesel vehicles for feeders.

Trunk Line 05. López Mateos has negative net cash flows in period 5 when it uses CNG technology on its trunk lines and diesel on its feeder lines, as shown in figure 32.

The following algebraic expression was used to calculate the NPV:

$$VPN = \sum_{t=0}^{5} \frac{Yn_t - COpN_t}{(1 + TMAR)^t}$$

Where:
Yn: total revenue in year t
$COpN$: total operating costs in year t
n: number of years in the evaluation horizon
$TMAR$: minimum Acceptable Rate of Return
t: calendar year, where year 0 will be the start of expenditures

Therefore, Trunk Route 05. López Mateos has the following net present value (VPN):

Indicador	Valor	Unidad
VPN Troncales y Alimentadoras diésel	-$250,984,830	$ mxn
VPN Troncales GNC y Alimentadoras diésel	-$73,851,123	$ mxn

Source: PGT, 2019

Figure 33. Net Present Value of Trunk Route 05. López Mateos

Note: NPV evaluation criteria: If the net present value (NPV) is ≥ 0, the investment is accepted; if the net present value (VPN) is < 0, the investment is rejected

Based on the sum of the net cash flows and discounting the minimum acceptable rate of return, the net present value for Trunk Route 05. López Mateos (when its fleet includes diesel vehicles) has a net present value (VPN) of -$250 984 830 MXN. VPNIn the case where the trunk lines use CNG and the feeders use diesel, the net present value is -$73 851 123 MXN. With the above values of the net present value (VPN), it is not recommended to accept the investment.

Internal rate of return (IRR)

The internal rate of return (IRR) is the discount rate at which the NPV equals zero, i.e., it is the rate that equals the discounted cash flows to the initial investment. The IRR was calculated using the following algebraic expression:

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$$VPN = \sum_{t=0}^{n} \frac{Yn_t - COpN_t}{(1 + TIR)^t} = 0$$

Where:
Yn: total income in year t
$COpN$: total operating costs in year t
n: number of years in the evaluation horizon
TIR: internal rate of return
t: calendar year, where year 0 is the start of expenditures

It is important to note that IRR should not be used alone to compare alternatives for a transportation investment project. The IRR for Trunk Route 05 is shown below:

Indicador	Valor	Unidad
TIR Troncales y Alimentadoras diésel	-26	Porcentaje
TIR Troncales GNC y Alimentadoras diésel	1	Porcentaje

Source: PGT, 2019

Figure 34. Internal Rate of Return for Trunk Route 05. López Mateos

Note: IRR evaluation criteria: If the IRR is greater than or equal to the discount rate, the investment is accepted. However, the IRR should not be calculated alone.

Based on the results of the IRR (TIR) above, it is concluded that for Trunk Route 05. López Mateos, both for the diesel vehicle fleet and for the fleet that uses CNG in its trunk routes and diesel feeders, with IRR values of -26 % and 1 %, respectively, it is not recommended to accept the investment.

Immediate recovery rate (TRI)

The Immediate Recovery Rate (TRI) is another profitability indicator that was used in the economic evaluation of Trunk Road 05 and made it possible to determine the optimal moment for the investment project to begin operations. Although the results of both the Net Present Value (VPN) and the Payback Period (TIR) may be favorable, this indicator must be taken into account. This calculation was performed using the following algebraic expression:

$$TRI = \frac{Yn_{t+1} - COpN_{t+1}}{I_t}$$

Where:
Yn: total revenue in year t
$COpN$: total operating costs in year t
I: total amount of the initial investment evaluated in year t
t: year prior to the first year of operation
t + 1: first year of operation of the trunk route

Monto total de la inversión inicial (I)	Año	Tasa Recuperación Inmediata (TRI)
244,719,764 (Año 0)	1	5.1%
	2	5.1%
	3	-3.5%
	4	-3.9%
	5	-11.3%
	6	-2.7%
	7	-2.7%
	8	-2.7%
	9	6.3%
	10	6.3%

Source: PGT, 2019

Figure 35. Immediate Recovery Rate for Trunk Route 05. López Mateos with diesel vehicle fleet

The optimal moment for a transportation project to begin operations and see increasing benefits over time should be the first year in which the operating margin (TRI) is equal to or greater than the operating ratio ($TMAR$), i.e., equal to or greater than 10 %. However, for Trunk Route 05, in the scenario where the fleet consists of diesel vehicles, a favorable TRI is not achieved, as shown in the figure 35.

RESULTS

Trunk Route 05. López Mateos, consisting of two trunk routes and six feeder routes, with a full fare of $9,50 and a transfer discount fare of $4,50, generates an estimated daily revenue of MXN 707 128. This value serves as a key reference for calculating daily revenue on subsequent trunk routes, highlighting the relevance and economic potential that this corridor represents within the public transportation system in the Guadalajara metropolitan area, Mexico. The need to replicate this algebraic formula to calculate revenue on subsequent trunk lines underscores the importance of thoroughly understanding and evaluating the financial performance of each corridor to achieve an accurate and equitable characterization of technical fares in the context of public transportation in this region.

Transport operators in the Guadalajara Metropolitan Area (AMG) maintain an approximate profit margin of 15 %. This figure suggests that, with the established technical fare and passenger levels, they can effectively cover the operating costs associated with providing public transport services.

On the other hand, in terms of the social fare, it can be seen that Mexican families allocate a significant portion of their income, around 13,4 %, to the consumption of transportation services. This proportion falls within the third-highest category in terms of consumption, highlighting the importance of transportation spending within the family budget and its impact on the domestic economy.

The population without income and a car in the Guadalajara Metropolitan Area (AMG) constitutes approximately 19,9 %, equivalent to about 875 000 people. Of this group, only 316 902 individuals are public transportation users, spending an average of $21,43 per day or $535,72 per month. It is inferred that these people receive financial support from a family member and can be found in various segments of the AMG population.

Users who earn between 0 and 2 times the minimum wage, representing 40,4 % of people without a car (approximately 643 359 users), spend an average of $565,00 per month on public transportation, which accounts for 13,6 % of their income. For this group, a social fare of $6,92 is estimated. Those who earn between 2 and 5 times the minimum wage could pay a social fare of around $10,68, and those with incomes above 5 times the minimum wage could bear a social fare of $21,66, $10,68, and those with incomes more than 5 times the minimum wage could afford a social fare of $21,66.

Considering that an individual earning the minimum wage ($123,22/day) and making four trips per day (Monday through Saturday) at a fare of $9,50 spends $912 per month. If that person belongs to a family of four who also make these trips, the household would spend $3648 per month. If the fare increased to $10, these expenses would rise to $960 and $3840, respectively. This situation is unsustainable, given that 64 % of the population in the state earns less than three minimum wages, according to INEGI data.

These findings reveal the complexities of transportation spending for different socioeconomic strata in the AMG, highlighting the need for more equitable social fare policies that are sensitive to the economic reality of the population. They also highlight the magnitude of the population affected by these financial implications in the context of public transportation in Guadalajara, Jalisco.

The resulting Net Present Value (NPV) for Trunk Line 05. López Mateos, considering diesel vehicles, yields an NPV of -MXN 250 984 830. In the scenario where the trunk lines use Compressed Natural Gas (CNG) and the feeders use diesel, the NPV is -MXN 73 851 123. Both NPV values indicate that the investment should not be accepted. After discounting the minimum acceptable rate of return and considering the net cash flows, it is clear that these projects do not generate sufficient economic returns to justify the investment. These findings underscore the importance of rigorously evaluating the financial and economic implications when considering the implementation of technologies and fleet models in public transportation in the Guadalajara metropolitan area, Mexico, providing key information for strategic decision-making in this area.

The Internal Rate of Return (IRR) results for the Troncal 05. The López Mateos route, both with the diesel vehicle fleet (-26 %) and with the combination of trunk lines using Compressed Natural Gas (CNG) and diesel feeders (1 %), confirms that it is not recommended to invest in either scenario. These IRR values suggest that, in both vehicle fleet configurations, the investment projects do not generate sufficient economic returns to justify their viability. This information is essential for understanding the profitability of fleet options for public transport on Trunk Line 05. López Mateos in Guadalajara, Mexico, emphasizes the need to strategically reassess investments based on the economic and financial viability of public transport projects in this metropolitan area.

In summary, a considerable gap is identified between the social fare and the technical fare proposed for public transport on Troncal 05. While the technical fare is based on operating costs and service sustainability, the social fare, designed to be accessible to low-income segments, reveals a considerable disparity in its

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application. This discrepancy suggests a potential limitation in equitable access to transportation for vulnerable populations, which may lead to disparities in urban mobility.

The difference between the technical fare and the social fare has a significant impact on lower-income households. Those who spend a significant proportion of their income on technical fare often experience financial difficulties when using public transport, which can impact their quality of life and access to opportunities. This situation underscores the need to review and adjust fare policies to alleviate the economic burden on the most vulnerable socioeconomic groups, ensuring a balance between service sustainability and accessibility for all sectors of society.

Regarding the technical fare for Troncal 05. López Mateos, the following conclusions and results can be drawn:

1. In the corridor of the Troncal 05. The López Mateos route has a population of 738 836 inhabitants and an estimated 430 744 jobs, with the highest concentration in the center of the municipality of Guadalajara.
2. The demand for public transportation in 2019 was 4,4 million trips per day.
3. The Troncal 05 López Mateos corridor, consisting of two trunk routes and six feeder routes, generates MXN 707 128 per day.
4. Different types of fares are analyzed: technical fare, zero-profit fare, social fare, weighted fare, and penalty fare.
5. Currently, the fare in force in the AMG is MXN 9,50, and a subsidy of MXN 500 000 000,00 has been announced, equivalent to a subsidy of 41 cents per passenger.
6. The low-income population, which represents 19,9 % of the AMG population, spends an average of $21,43/day or $535,72 per month on public transportation.
7. Sixty-four percent of the state's population earns less than three times the minimum wage, making public transportation a significant burden for these families.
8. The net present value (NPV) of Trunk Road 05. López Mateos' investment with diesel vehicles is -MXN 250 984 830, while with CNG on trunk roads and diesel on feeder roads, it is -MXN 73 851 123, suggesting that investment in both cases is not recommended.
9. The internal rate of return (IRR) for the Troncal 05. López Mateos' route is -26 % with diesel vehicles and 1 % with CNG on trunk lines and diesel on feeder lines, which also indicates that the investment should not be accepted.
10. The first year in which the IRR is equal to or greater than the MARR (10 %) is the optimal time for a transportation project to begin operation, but this is not achieved in the case of the Troncal 05 route with diesel vehicles.

Thus, the analysis presented on the technical fare and economic evaluation shows that public transport demand is high in the Guadalajara metropolitan area and that public transport expenditure is a burden on low-income families. Different types of fares are discussed, along with investments in Troncal 05. López Mateos' route is evaluated, but the results indicate that the investment should not be accepted in the scenarios analyzed.

Finally, the above results can be related to the objectives of this study as follows:

1. Characterize the technical, fair, and sustainable fare for public transportation known as the "Mi Transporte" Integrated Transportation Model, under the route-company scheme in the Guadalajara metropolitan area, specifically Troncal 05. López Mateos. The results show the cost structure of public transport in the AMG, including direct and indirect costs, operating expenses, and the cost generated by discount tickets. It also analyzes how the social fare could be determined considering different income groups and their ability to pay. These results help to understand and characterize the technical, fair, and sustainable fare for the public transport system in Guadalajara.
2. Assess the behavior of the main operating costs of the AMG's "Mi Transporte" Integrated Transportation Model. Case study: Troncal 05. López Mateos. The total revenue generated by the production of the Troncal 05 route service is analyzed, along with the operating costs associated with the use of diesel and CNG vehicles. This information enables the measurement of the system's main operating costs and understanding how these costs impact its technical and sustainable performance.
3. Explain the fare scheme of the AMG's "Mi Transporte" Integrated Transport Model. Different types of fares are described, including technical fare, zero-profit fare, social fare, weighted fare, and penalty fare. Additionally, the report examines Jalisco's use of direct and indirect subsidies for public transportation. These results provide a clear explanation of the current fare scheme and suggest ways to improve it, ensuring a fair and sustainable fare.
4. Develop an econometric and economic evaluation model to calculate the technical, fair, and sustainable fare using demand elasticities and transportation service indicators from the AMG's "Mi

Transporte" integrated transportation model for 2019. Case Study 05. López Mateos. The results of the demand, cost, and revenue analysis made it possible to develop an econometric model (algebraic expression 4,19, page 130) and an economic evaluation model that takes into account demand elasticities and transport service indicators. Additionally, relevant information for constructing this model is provided, including existing demand and the costs associated with different vehicle and technology options.

The results obtained therefore provide a solid basis for addressing the objectives set out in terms of characterizing a technical, fair, and sustainable fare, the behavior of operating costs, the fare scheme, and the development of an econometric and economic evaluation model for the "Mi Transporte" public transport system in the AMG, specifically Trunk Line 05. López Mateos.

CONCLUSIONS

The study of the public transport system in the Corridor of Troncal 05. López Mateos, as well as the evaluation of its efficiency and quality of service, is fundamental for the design and implementation of public policies and intervention strategies that contribute to improving urban mobility and the quality of life of the inhabitants of the AMG. Through the adoption of a comprehensive and participatory approach, it is possible to move towards consolidating a more accessible, efficient, and sustainable public transport system that responds to the needs and expectations of citizens and promotes human and sustainable development in the region.

This thesis demonstrates that technical, social, and sustainable aspects of public transportation fares are a topic of interest to governments, transportation operators, researchers, experts, and users.

It also concludes that in the state of Jalisco, Mexico, the Mobility and Transportation Law regulates the principles under which public transportation services must be provided and establishes standards and indicators to evaluate service quality. The Declaration of Need for 18 trunk mobility routes and 86 complementary routes for the General Transportation Program for the Integrated Public Transportation System in the Guadalajara Metropolitan Area, Jalisco, is issued based on these principles and standards.

Currently, Mexico has the General Law on Mobility and Road Safety, and the State of Jalisco is expected to harmonize and publish its New Law on Mobility and Road Safety in 2023.

In Guadalajara, Origin-Destination Studies (ODS) have been conducted at various times by different government and private entities, although not as consistently as desired. However, urban mobility projects in the Guadalajara Metropolitan Area (AMG) have been ongoing and justified by data collected in previous studies. Among the most notable projects are:

For this reason, over the years, the issue of technical, social, and sustainable public transport fares has been of great importance both globally and locally. Studies conducted in various regions have underscored the necessity for an integrated fare policy that considers demand and the financial viability of public transportation. In the specific case of the state of Jalisco and the city of Guadalajara, laws, regulations, and projects have been implemented to enhance the quality, efficiency, and accessibility of the public transportation system.

As Guadalajara continues to grow and face urban mobility challenges, it is essential to maintain a focus on updating and implementing appropriate and sustainable fare policies. In addition, it is necessary to continue implementing and updating Origin-Destination studies to maintain the effectiveness of mobility projects and ensure that public transport remains accessible and efficient for all citizens. In the long term, these efforts can contribute to enhancing the quality of life for Guadalajara's residents and promoting the city's sustainable development.

As a conclusion to the analysis of demand elasticities in Chapter II, point 3, we can conclude that:

1. The elasticity of demand for public transport can be elastic or inelastic, depending on how the quantity demanded responds to changes in the fare. Demand is elastic when the quantity demanded is susceptible to changes in the fare, and inelastic when the quantity demanded varies little with the fare.
2. An increase in the fare may lead to a decrease in the quantity demanded and, therefore, a decrease in the total revenue of the transport operator. On the other hand, a decrease in the fare may increase the quantity demanded and, consequently, total revenue.
3. The demand for public transportation can be influenced by factors such as the proportion of transportation expenditure in users' budgets, the availability of substitute goods, the quality and comfort of the service, and the rate of motorization.
4. Demand for services that represent a significant portion of users' budgets tends to be elastic. In contrast, demand for services that constitute a small portion of the budget tends to be inelastic.
5. Services with many substitute goods tend to have elastic demand, while services with few substitute goods tend to have inelastic demand.
6. Long-term demand is usually more elastic than short-term demand, as users have more time to adapt to changes in the fare.

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In this sense, the thesis describes how public transport demand in the AMG is affected by fare changes and how various factors can influence demand elasticity. Understanding these dynamics can help inform fare and policy decisions in the public transport sector.

As conclusions from the theoretical application to the case of the Troncal 05. López Mateos route, we can conclude that:

1. The technical fare, proposed by economist William Vickrey, seeks to cover the operating and maintenance costs of public transport without generating profits for the transport company. Its objective is to ensure the efficient and sustainable operation of public transport.
2. The application of technical fares can contribute to greater equity in the distribution of public transport costs and ensure sustainable financing of the service. However, concerns exist about the viability and social acceptance of technical fares, as well as issues with implementing and calculating the actual costs of public transport.
3. The PGT trunk routes may resort to setting fares based on marginal costs rather than average costs, especially in market situations that are far from perfect competition. Marginal pricing can generate conflicts between modes of transport and companies, which may prompt the intervention of the Transport Secretariat (SETRAN) in fare regulation.
4. Urban road pricing is an effective tool in public transport policy for improving sustainability in large cities. However, one of the main problems for its implementation is low social acceptance.
5. It can be seen that social acceptance of the pricing system proposed in Chapter II, section 4.2, is based on two determining factors: the social perception of congestion as a priority problem to be solved and the adequate level of availability of the transport system as a competitive alternative to the car. The fare has high social acceptance because citizens recognize that greater use of public transport means less pollution from private car use. This may be similar to the case of the city of Madrid, as Muñoz et al.[104] explain.

About the social fare and as a contribution of this thesis, we can conclude that:

1. Equity in public transport fares is essential to ensure fair and equitable access for all citizens, especially those with low incomes or living in disadvantaged areas.
2. A progressive fare system based on users' ability to pay, as proposed by Vickrey[131], can help achieve greater access and equity in public transport.
3. There are various reduced and special fares, such as work, student, child, senior citizen, and night fares, among others, which aim to improve equity and accessibility to public transport.
4. Defining a socially fair fare for AMG transportation is an important issue for authorities such as SETRAN, IMEPLAN, and the Municipal Mobility Directorates that regulate mobility.
5. Research by Jaramillo et al.[84] reveals that there is a relationship between the speed of public transport vehicles and the fare required to maintain a balance between the system's costs and revenues: the higher the speed, the lower the fare to be paid by the user. Therefore, SETRAN and IMEPLAN should conduct studies or constant monitoring of routes and companies.
6. Optimizing the operating and maintenance costs of the Troncal 05. López Mateos, as well as reducing the number of kilometers traveled by each vehicle without affecting service levels, can result in a reduction in the fare.
7. The procedures applied in the study by Jaramillo et al.[84] can be replicated in the AMG, contributing to the search for a socially fair public transport fare.

The theory of sustainability, which originated in the Brundtland report, has been adopted globally and seeks to balance economic development, social equity, and environmental protection for long-term sustainable development.

The sustainability approach applied to public transport considers the environmental, social, and economic aspects associated with urban mobility, promoting less polluting, socially equitable, and economically viable transport options. The AMG has the Mibi and civlovías system, a 100 % electric route, CNG buses, a trolleybus route (hybrid), among others.

The United Nations Sustainable Development Goals (SDGs) establish a global framework for social and environmental action, and sustainable urban mobility is a key aspect of achieving these goals.

Sustainable urban mobility involves meeting current mobility needs without compromising the ability of future generations to meet their own needs, taking into account economic, environmental, and social aspects.

Research and experience in the field of sustainable urban mobility highlight the importance of shifting the focus toward a model centered on public and non-motorized transportation, as well as urban planning and investment in adequate infrastructure.

To achieve more sustainable and efficient urban mobility, the AMG must adopt comprehensive approaches,

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encourage citizen participation, and seek solutions tailored to its specific contexts.

A detailed study of the public transport system on the Troncal 05 route, López Mateos, and an assessment of its efficiency and quality of service are essential to understanding the dynamics of urban mobility. It is suggested that the feasibility of implementing progressive and sustainable fares, adjusted to users' ability to pay, be investigated. This approach would contribute to a more equitable and accessible transport system for all socioeconomic strata.

Additionally, the implementation of public policies aimed at establishing socially fair and sustainable fares for public transportation is crucial for improving the quality of life and urban mobility in the Guadalajara Metropolitan Area (AMG). A comprehensive review of fares is proposed, considering subsidies, differentiated fares, and economic evaluation models to ensure a balance between the financial sustainability of the service and accessibility for all citizens. Furthermore, it is recommended that studies such as the Origin-Destination Studies (EOD) be continued to support public decisions and policies on urban mobility.

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