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ORIGINAL

Impact of the macrobus line on users' origin-destination travel times and costs, Guadalajara metropolitan area, 2012

Impacto de la línea del macrobús en los costos y tiempos totales de traslado origen-destino de los usuarios, zona metropolitana de Guadalajara 2012

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ABSTRACT

Introduction: we analyzed the impact of the BRT system, Macrobús, on origin-destination (O-D) costs and travel times in the Guadalajara Metropolitan Area (ZMG), considering individual characteristics of users and their frequency of use.
Method: they applied an O-D survey to 384 users over 15 years of age in May 2012, in the 27 stations of the corridor. They used Aschman's method and software such as SPSS, STATA and Excel for processing. They classified users into low, medium and high frequency. They evaluated variables such as gender, age, income, transfer time and cost, perception of service, and number of transfers.
Results: they determined that 66,41 % of the users reported shorter travel time after the implementation of the Macrobús. A total of 85,16 % did not perceive an increase in costs, and only 14,84 % did. Most of the users were women, young and low-income. They confirmed statistically significant associations between frequency of use and variables such as occupation, monthly income, travel time and number of transfers. However, there was no significant association with age, sex, schooling or perception of the service.
Conclusions: they confirmed that the Macrobús system reduced commute times and had a minimal economic impact for the majority. They concluded that public policies are needed to strengthen multimodal transportation integration and promote intermunicipal connectivity. The objective of the study was met by demonstrating the positive impact of the system based on the characteristics and frequency of use of the users.

Keywords: Macrobús; Transfer; Frequency; ZMG; Transportation.

RESUMEN

Introducción: analizaron el impacto del sistema BRT, Macrobús, en los costos y tiempos de traslado origen-destino (O-D) en la Zona Metropolitana de Guadalajara (ZMG), considerando características individuales de los usuarios y su frecuencia de uso.
Método: aplicaron una encuesta O-D a 384 usuarios mayores de 15 años en mayo de 2012, en las 27 estaciones del corredor. Utilizaron el método de Aschman y software como SPSS, STATA y Excel para el procesamiento. Clasificaron a los usuarios en baja, media y alta frecuencia. Evaluaron variables como sexo, edad, ingreso, tiempo y costo de traslado, percepción del servicio, y número de transbordos.
Resultados: determinaron que el 66,41 % de los usuarios reportaron menor tiempo de traslado tras la implementación del Macrobús. El 85,16 % no percibieron aumento en costos, y solo el 14,84 % sí. La mayoría de los usuarios eran mujeres, jóvenes y con ingresos bajos. Confirmaron asociaciones estadísticamente significativas entre la frecuencia de uso y variables como ocupación, ingreso mensual, tiempo de traslado y número de transbordos. Sin embargo, no hubo asociación significativa con edad, sexo, escolaridad o percepción del servicio.

Conclusiones: confirmaron que el sistema Macrobús redujo tiempos de traslado y tuvo un impacto económico mínimo para la mayoría. Concluyeron que se necesitan políticas públicas que fortalezcan la integración multimodal del transporte y promuevan la conectividad intermunicipal. El objetivo del estudio se cumplió al demostrar el impacto positivo del sistema en función de las características y frecuencia de uso de los usuarios.

Palabras clave: Macrobús; Traslado; Frecuencia; ZMG; Transporte.

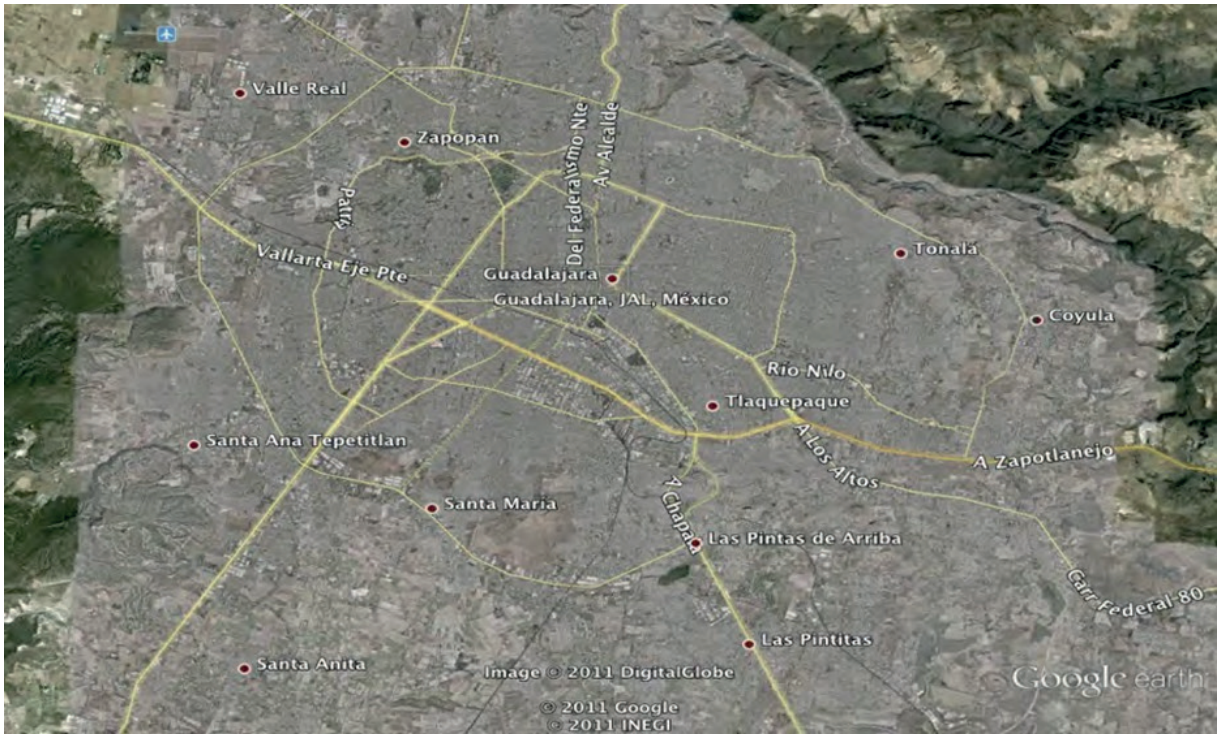
INTRODUCTION

This paper aims to analyze the impact of the introduction of the BRT (Bus Rapid Transit) system known as Macrobús on the total origin-destination (O-D) travel costs and times of users according to the intensity with which they use this means of transportation in the Guadalajara Metropolitan Area (ZMG), as well as other relevant characteristics.[1,2,3,4,5,6] The study addresses issues ranging from the international and local context to the results of the "Survey of Macrobús Users in the ZMG conducted in 2012" (EMZMG).[7,8,9,10,11,12]

In addition, a variable called "daily Macrobús user" is generated and classified into three categories: low, medium, and high frequency users.[13,14,15,16,17,18] Next, using contingency tables with the SPSS statistical package, an inferential analysis will be performed to determine the associations between individual user characteristics such as gender, age, occupation, education, average monthly income, total cost of travel,[19,20,21,22,23,24] total travel time, users' perception of total travel time, users' perception of total transportation cost,[25,26,27,28,29,30] number of transfers at origin, and number of transfers at destination, according to the daily intensity of trips made using this means of mass transportation in the ZMG.[31,32,33,34,35,36]

With the above, the degree of association is reviewed by applying the Chi-square analysis (with at least 10 % significance) between variables and determining whether there is interdependence between them.[37,38,39,40,41]

In this regard, the results obtained allow us to analyze the impact of this system on the total origin-destination (O-D) travel costs and times of users according to their characteristics and travel intensity.[42,43,44,45] This study also aims to be relevant, accessible, and useful for decision-making on urban mobility projects in the ZMG.[46,47,48]



Source: Google Earth 2011
Figure 1. Guadalajara Metropolitan Area

How does the BRT system known as Macrobús impact the total origin-destination (O-D) travel costs and times of users according to their individual characteristics and the intensity with which they use this means of transportation in the ZMG?

Objective

To analyze how the BRT system known as Macrobús impacts the total origin-destination (O-D) travel costs and times of users according to their individual characteristics and the intensity with which they use this means of transportation in the ZMG.

METHOD

The background information already presented agrees that international empirical evidence on the operation of a BRT system shows that BRT is a good alternative in terms of cost-benefit, not only for the public transport service provider, but also for the consumer/user. The latter enjoys the benefits generated by the savings of the former. For example, the increase in average travel speed, the increase in safety, and the reduction in travel times.

The hypothesis of this study is to demonstrate that the implementation of the BRT system known as Macrobús has a positive impact on the total origin-destination (O-D) travel costs and times for users.

Methodology, design, and survey collection

To test the hypothesis proposed in this research paper, the general procedure for origin-destination surveys recommended by Aschman[1] in the document "Development of the Methodology and Planning Stages of Origin-Destination" was used. The procedure was divided into four components: survey preparation; survey administration; survey data capture and validation; and results processing. Each step of the survey is described below.

The survey preparation process

Delimitation of the study area

In the survey preparation process, the study area was first delimited, which corresponds to the route of the Macrobús trunk line, covering 16 km of the corridor within the municipality of Guadalajara, with 27 stations, namely: 1) Viewpoint, 2) Huentitán, 3) Zoo, 4) North Independence,5) St. Patrick, 6) Equality, 7) Monumental, 8) Monte Olivete, 9) Circunvalación, 10) Health Sciences, 11) Juan Álvarez, 12) Alameda, 13) St. John of God, 14) Bicentennial, 15) La Paz, 16) Niños Heroes, 17) Blue Water, 18) Ciprés, 19) Heroe de Nacozari, 20) Lázaro Cárdenas, 21) El Deán, 22) Industrial Zone, 23) López de Legazpi 24) Clemente Orozco, 25) Plastic Arts, 26) Sculptures, and 27) Fray Angélico.

This trunk line also operates with 41 articulated buses and 103 conventional buses that operate on 15 feeder routes.

Zoning

The Calzada Independencia corridor has a population of 166 691 and an area of 1661,51 hectares, representing a density of 100,33 inhabitants per hectare (inhab/ha). There are 1782 blocks around the corridor (2). Land use in the corridor is shown in the following table:

Table 1. Land use in the Calzada Independencia Corridor

Concept	Area (Ha)	
Residential	401,8	24,1
Urban facilities	317,5	19,11
Industrial	314,80	18,95
Mixed Neighborhood	187,12	11,26
Central Mixed	171,01	10,29
District Mixed	84,56	5,09
Commercial	65,24	3,9
Other	65,32	3,93
Special infrastructure	57,07	3,25
Total	1661,51	1

Source: Urban Indicators of the Mass Transportation Strategy for the ZMG[2]

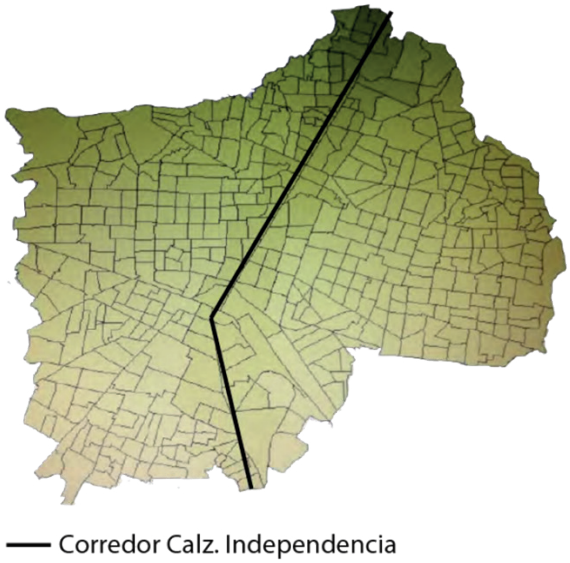
Similarly, the various types of activities carried out in the corridor, with their respective economic units, can be seen in table 2. It can be seen that the tertiary sector has the most economic units and, in turn, has the most units dedicated to commerce.

Table 2. Economic units by sector in the Calzada Independencia Corridor

Sector	Economic units	Percentage
PRIMARY	0	0
SECONDARY	1167	9,11
TERTIARY	11 639	90,89
Total	12 806	100
Services	4245	36,47
Commercial	7394	63,53
Total	11 639	100,00

Source: Urban Indicators of the Mass Transportation Strategy for the ZMG[2]

In addition, this corridor is made up of 82 AGEBs (Basic Geostatistical Areas), which can be seen in the following figure:



Source: Urban Indicators of the Mass Transportation Strategy for the ZMG[2]
Figure 2. Total number of AGEBs that make up the Calzada Independencia Corridor

Sample design

The sample design was based on probability sampling, with a 95 % confidence level and a 5 % margin of error. The target population is users aged 15 and over who travel on the BRT system (125 000) 4. The survey was conducted throughout the day, covering the peak and off-peak periods, i.e., the periods of maximum and low demand, both in the morning and in the afternoon. i.e., periods of peak and low demand, both in the morning and afternoon.

The formula for determining the sample size "n" when the population "N" is known:[3]

$$n = \frac{(Z)^{\&}\, p\, q\, N}{NE^{\&} + Z^{\&}\, p\, q} = \frac{(1.96)^{\&}(0.5)(0.5)(125{,}000)}{(125{,}000)(0.05)^{\&} + (1.96)^{\&}(0.5)(0.5)}$$

$$= \frac{(3.8416)(.25)(125{,}000)}{(125{,}000)(.0025) + (3.8416)(.25)} = \frac{120{,}050}{313.4604} = \mathbf{383}$$

383 = the number of surveys administered to users aged 15 and over who travel on the BRT system during the day and are distributed across the 27 stations.

Where:

Z: Critical value of the Z distribution, with a 95 % confidence level.

N: Population.

n: Sample of the population.
p: Variability of the event being +0,5 q: Variability of the event being -0,5
E: Alpha error 1- α = 95 %, α = 0,05 %.

Question

The purpose of this questionnaire is to gather information on the following main aspects: the origin and destination of trips, the chain of means of transport used, the reasons for the trip, travel times, and the sociodemographic characteristics of users, among other aspects.

Fecha de aplicación (__/__/__)
Hora de inicio de encuesta (__ : __)
Hora fin de encuesta (__ : __)
Estación
Encuestador _____

Cuestionario
INSTRUCCIONES: Selecciona la respuesta correcta
Perfil del usuario
1. Sexo
Mujer Hombre
2. ¿Cuál es su edad?
A) 15 a 24 años B) 25 a 39 años C) 40 a 49 D) 50 a 59 E) 60 a 69 F) 70 y más.
3. ¿Cuál es su último grado de estudios? _____
4. ¿Cuál es su Ocupación?
A) Estudiante B) Ama de casa C) Empleado empresa privada D) Empleado de gobierno
E) Trabajador independiente F) Patrón ó empresario
H) Jubilado/Pensionado I) Desempleado que busca trabajo
5. ¿Cuántos viajes en macrobús realiza al día:
Lun_____ Jue_____ Dom_____
Mar Vier
Miér._____ Sáb_____
INSTRUCIONES: Selecciona la respuesta correcta y contesta en los espacios.
6. ¿Dónde inició su viaje para llegar a esta estación de macrobús (Origen)?
A) Casa B) Trabajo C) Escuela D) Otro (Nombre)_____
Ubicación de origen.
Calle_____ Alguna referencia_____
Colonia_____ Municipio_____
7. ¿A qué hora comenzó tu viaje… (según la respuesta en la pregunta 6) ? Hora:_____Min:_____
8. ¿A qué hora llegó a la estación? Hora:_____Min:_____
9. ¿Qué medio utilizó para llegar aquí, antes que Macrobús? (Si la respuesta es "A" o "B" pasar a pregunta 11)
A) A pie B) Bici C) Taxi D) Auto E) Alimentador F) Transp. Público G) Transp. De Pers.
H) Tren I) Otro_____
10. ¿Cuál fue la forma de pago de tu viaje?
A) Monedas B) Tarjeta Prepagada Normal C) Tarjeta prepagada Personalizada D) Transvale
11. ¿Cómo pagó usted el viaje de Macrobús?
A) Monedas B) Tarjeta Prepagada Normal C) Tarjeta prepagada Personalizada
12. ¿Cuál es tu destino después de la estación?
A) Casa B) Trabajo C) Escuela D) Otro_____

Figure 3. Questionnaire format for origin-destination survey. Sheet 1

Ubicación de destino.
Calle_____ Alguna referencia_____
13. ¿Utilizarás otro medio de transporte después de Macrobús para llegar a tu destino final? Según la respuesta 12 (Si la respuesta es "A" o "B" pasar a pregunta 15)
A) A pie B) Bici C) Taxi D) Auto E) Alimentador F) Transp. Público G) Transp. De Pers.
H) Tren I) Otro_____
14. ¿Cuál sería la forma de pago para tu siguiente viaje?
A) Monedas B) Tarjeta Prepagada Normal C) Tarjeta prepagada Personalizada D) Transvale

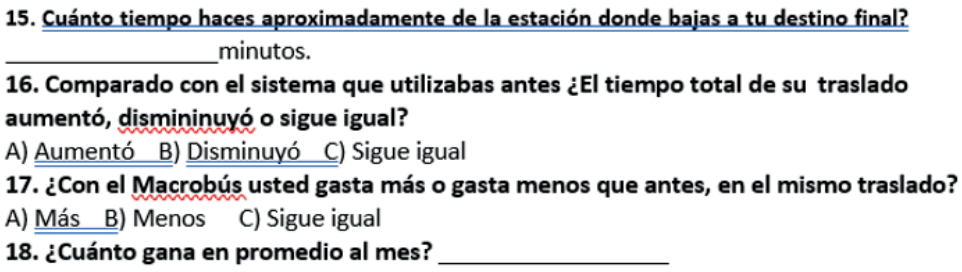

15. Cuánto tiempo haces aproximadamente de la estación donde bajas a tu destino final?
_____minutos.
16. Comparado con el sistema que utilizabas antes ¿El tiempo total de su traslado aumentó, dismininuyó o sigue igual?
A) Aumentó B) Disminuyó C) Sigue igual
17. ¿Con el Macrobús usted gasta más o gasta menos que antes, en el mismo traslado?
A) Más B) Menos C) Sigue igual
18. ¿Cuánto gana en promedio al mes? _____

Figure 4. Questionnaire format for origin-destination survey. Sheet 2

Application of the survey

At this stage, a work program was developed and, with the sample size defined, users aged 15 and over who travel on the Macrobús system along the corridor were surveyed, starting in both directions. The survey was conducted from May 7 to 19, 2012, in four periods of the day: from 6:00 a.m. to 10:00 a.m.; 10:00 a.m. to 2:00 p.m.; 2:00 p.m. to 6:00 p.m.; and 6:00 p.m. to 10:00 p.m. in order to cover both morning and afternoon peak and off-peak hours.

In addition, a team of five people per day was available with the necessary survey materials (tables, pens, and questionnaires).

The five people were selected and trained, and the surveyors were taught the survey procedure. In addition, one of us served as a supervisor to review how the surveyors filled out the forms and used the materials.

The training was conducted with a simulation exercise at a station in order to detect errors, clarify doubts, and visualize some specific situations that could arise with the guards and users and how to handle them. The simulation was conducted as if it were the actual survey, and real users of the San Juan de Dios station were surveyed at 10:00 a.m.

Finally, the questionnaire was administered to users at the stations, face-to-face, with an average duration of 3 minutes, and each format was reviewed to ensure its validity.

Coding, data entry, and validation

This process consisted of writing the number corresponding to the station on each questionnaire, i.e., from 1 to 27. Finally, at this stage, the information relating to the questionnaires was organized, the quality of the information collected was verified, and it was delivered to the supervisor.

The purpose of data entry is to enter the information associated with the survey into the computer system, duly coded by station number. It is important to establish a set of guidelines governing the entry of survey data in order to minimize errors, some of which are as follows: typing errors (data entry) due to the limited time available to users to answer.

Processing of results

Once the surveys were completed, the database was compiled, and the information was validated, processed, and results were generated using STATA, SPSS, and Excel software. These packages were selected due to their ease of use and data management capabilities.

In addition, a series of contingency tables were created to obtain variables such as cost-time indicators and to perform hypothesis testing and Chi-square tests.

Table 3. Surveys conducted by time of day

Frequency			Percentage	Valid percentage	Cumulative percentage
Valid	6:00 a.m. to 10:00 a.m.	101	26,3	26,3	26,3
	10:00 a.m. to 2:00 p.m.	101	26,3	26,3	52,6
	2:00 p.m. to 6:00 p.m.	99	25,8	25,8	78,4
	6:00 p.m. to 10:00 p.m.	83	21,6	21,6	100,0
	Total	384	100,0	100,0	

The objective of distributing the surveys at these four times of day is to survey system users during peak and off-peak hours (off-peak hours are considered to be times of low demand) throughout the day, i.e., from 6:00 a.m. to 10:00 a.m., 10:00 a.m. to 2:00 p.m., 2:00 p.m. to 6:00 p.m., and 6:00 p.m. to 10:00 p.m. The surveys were distributed at the 27 stations along the Calzada Independencia-Gobernador Curiel corridor based on demand and are presented in figure 6 and figure 7 below.

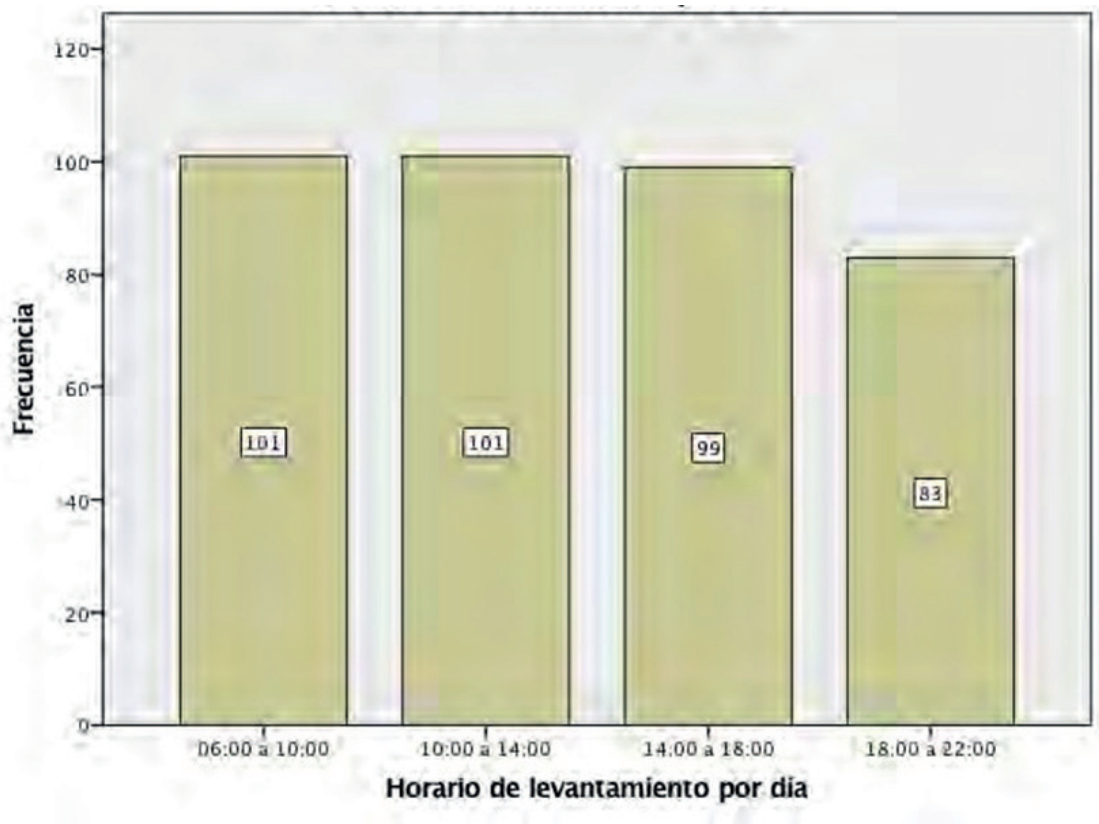


Figure 5. Frequency of surveys by time of day

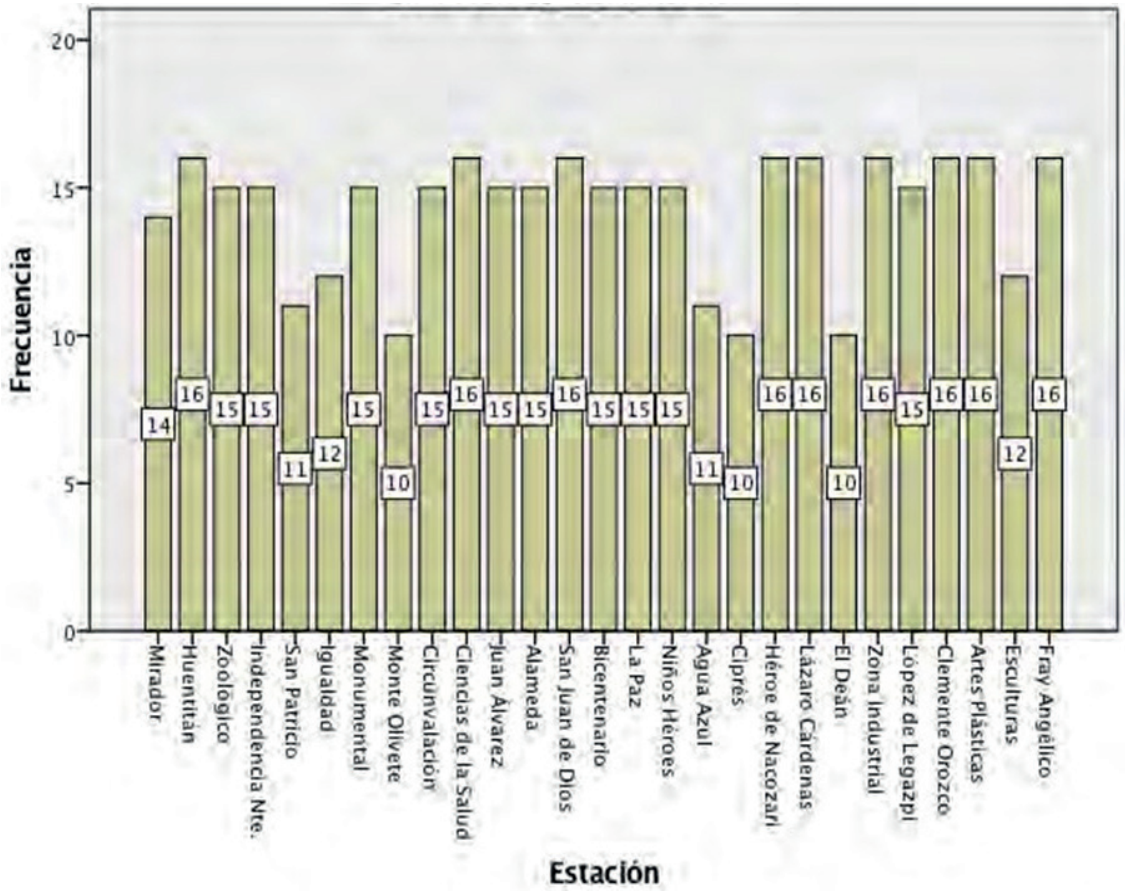


Figure 6. Frequency of surveys by station

No.	Estación	Horario 1 06:00 a 10:00	Horario 2 10:00 a 14:00	Horario 3 14:00 a 18:00	Horario 4 18:00 a 22:00
		Encuestas realizadas			
1	Mirador	4	3	4	3
2	Huentitán	5	4	4	3
3	Zoológico	4	4	4	3
4	Independencia Nte.	4	4	4	3
5	San Patricio	3	3	3	2
6	Igualdad	3	4	3	2
7	Monumental	4	4	4	3
8	Monte Olivete	2	3	3	2
9	Circunvalación	4	4	4	4
10	Ciencias de la Salud	4	4	4	3
11	Juan Álvarez	4	4	4	3
12	Alameda	4	4	4	3
13	San Juan de Dios	4	4	4	4
14	Bicentenario	4	4	4	3
15	La Paz	4	4	4	3
16	Niños Héroes	4	4	4	3
17	Agua Azul	3	3	3	2
18	Ciprés	3	3	2	2
19	Héroe de Nacozari	4	4	4	4
20	Lázaro Cárdenas	4	4	4	4
21	El Deán	3	3	2	2
22	Zona Industrial	4	4	4	4
23	López de Legazpi	4	4	4	3
24	Clemente Orozco	4	4	4	4
25	Artes Plásticas	4	4	4	4
26	Esculturas	3	3	3	3
27	Fray Angélico	4	4	4	4
Totales		101	101	99	83

Figure 7. Surveys conducted by station and time of day

Figure 8 shows that the 10 neighborhoods that generate the most trips for Macrobús users are Centro with 11,73 % of trips, Huentitán el Bajo with 10,42 %, the industrial zone with 6,19 %, Independencia with 5,21 %, Miravalle (Guadalajara section) with 4,89 %, Ferrocarril with 4,56 %, Higuerillas with 4,23 %, Independencia Ote. 3,91 %, Lomas del Paraíso 2,93 %, Panorámica de Huentitán with 2,93 %, and 47 % distributed among the other neighborhoods of Guadalajara surrounding the corridor.

For the municipality of Zapopan, the five main neighborhoods generating trips are: Industrial Belenes, El Colli, Jardines de la Patria, Tesistan, and Arcos de Guadalupe. Similarly, for Tlaquepaque, the five main neighborhoods generating trips are: Miravalle, El Vergel, Las Juntas, Lomas del 4, and Fovisste Miravalle.

In Tonalá, the study shows that only four neighborhoods generate trips for Macrobús system users: El Rosario, Lomas del Camichi I, Paseo del Valle, and Zalatitán. Similarly, for Tlajomulco de Zúñiga, only three neighborhoods generate trips for Macrobús system users: Centro, La Concha (Chulavista), and Lomas de San Agustín. And for El Salto, the neighborhoods are Centro, El Verde, El Zapote, and Ermita.

Origen de viajes por Colonias de Guadalajara					
Colonia	**Porcentaje**	**Colonia**	**Porcentaje**	**Colonia**	**Porcentaje**
Centro	11.73%	La Perla	0.98%	Bosques de la Victoria	0.33%
Huentitán el bajo	10.42%	Monumental	0.98%	Centro Barranquitas	0.33%
Zona Industrial	6.19%	Santa Tere	0.98%	Colomos Providencia	0.33%
Independencia	5.21%	Colinas de la Normal	0.65%	Cuauhtémoc	0.33%
Miravalle	4.89%	El Déan	0.65%	El Cármen	0.33%
Ferrocarril	4.56%	El Mirador	0.65%	Hermosa Provincia	0.33%
Higuerillas	4.23%	Fovissste Estadio	0.65%	Insurgentes	0.33%
independencia Oriente	3.91%	Infonavit Estadio	0.65%	Jardines Alcalde	0.33%
Lomas del Paraíso	2.93%	Jardines de la Cruz	0.65%	Jardines de Guadalupe	0.33%
Panorámica de Huentitán	2.93%	La esperanza	0.65%	La Aurora	0.33%
5 de mayo	2.61%	La Federacha	0.65%	La Joyita	0.33%
8 de julio	1.95%	Mexicaltzingo	0.65%	Ladrón de Guevara	0.33%
Circ. Belisario	1.63%	Oblatos	0.65%	Los arrayanes	0.33%
El Retiro	1.63%	Olimpica	0.65%	Miraflores	0.33%
Lomas de Independencia	1.63%	Rincón del Agua Azul	0.65%	Obrera	0.33%
Morelos	1.63%	San Marcos	0.65%	Progreso	0.33%
Rancho Nuevo	1.63%	Santa Elena Alcalde	0.65%	Quinta Velarde	0.33%
Alcalde Barranquitas	1.30%	18 de marzo	0.33%	Ricardo Flores Magon	0.33%
Belisario Domíguez	1.30%	Analco	0.33%	San Carlos	0.33%
Clemente Orozco	1.30%	Arcos	0.33%	San Elias	0.33%
El Manantial	1.30%	Atlas	0.33%	Talpita	0.33%
La Nogalera	1.30%	Balcones de Oblatos	0.33%	Verde Valle	0.33%
Americana	0.98%	Barragán y Hernández	0.33%	Villas de San Juan	0.33%
Jardines del Sur	0.98%	Beatriz Hernández	0.33%		

Figure 8. Origin of trips by neighborhood in Guadalajara

Origen de viajes por Colonias de Zapopan	
Colonia	**Porcentaje**
Industrial belenes	16.67%
El Coli	12.50%
Jardines de la patria	8.33%
Tesistan	8.33%
Arcos de Guadalupe	4.17%
Auditorio	4.17%
Centro	4.17%
Chapalita	4.17%
Ciudad del sol	4.17%
El Batán	4.17%
Fracc. Providencia	4.17%
Jardines los Belenes	4.17%
Jardines Universidad	4.17%
Las Agujas	4.17%
Las fuentes	4.17%
Nuevo Vergel	4.17%
Residencial del Valle	4.17%

Figure 9. Origin of trips by neighborhood in Zapopan

Origen de viajes por Colonias deTlaquepaque	
Colonia	**Porcentaje**
Miravalle	24.39%
El vergel	14.63%
Las Juntas	12.20%
Lomas del 4	9.76%
Fovissste Miravalle	4.88%
Francisco I. Madero	4.88%
Alamo Industrial	2.44%
Artesanos	2.44%
Centro	2.44%
Cerro del 4	2.44%
El Álamo	2.44%
El Campesino	2.44%
El Mirador	2.44%
Guadalupe Ejidal	2.44%
Las vegas	2.44%
Lomas de Tlaquepaque	2.44%
Sta. María Tequepexpan	2.44%
Villa Fontana	2.44%

Figure 10. Origin of trips by neighborhood in Tlaquepaque

Origen de viajes por Colonias de Tonalá	
Colonia	**Porcentaje**
El Rosario	25%
Lomas del Camichin I	25%
Paseo del Valle	25%
Zalatitán	25%

Figure 11. Origin of trips by neighborhood in Tonalá

Origen de viajes por Colonias deTlajomulco	
Colonia	**Porcentaje**
Centro	25%
La Concha	50%
Lomas de San Agustín	25%

Figure 12. Origin of trips by neighborhood in Tlajomulco

Origen de viajes por Colonias de El Salto	
Colonia	**Porcentaje**
Centro	25%
El Verde	25%
El Zapote	25%
Ermita	25%

Figure 13. Origin of trips by neighborhood in El Salto

Contrary to the information described in the tables on trips by municipality and neighborhood of origin, figure 6 summarizes the frequency of trips by Macrobús users by neighborhood of origin.

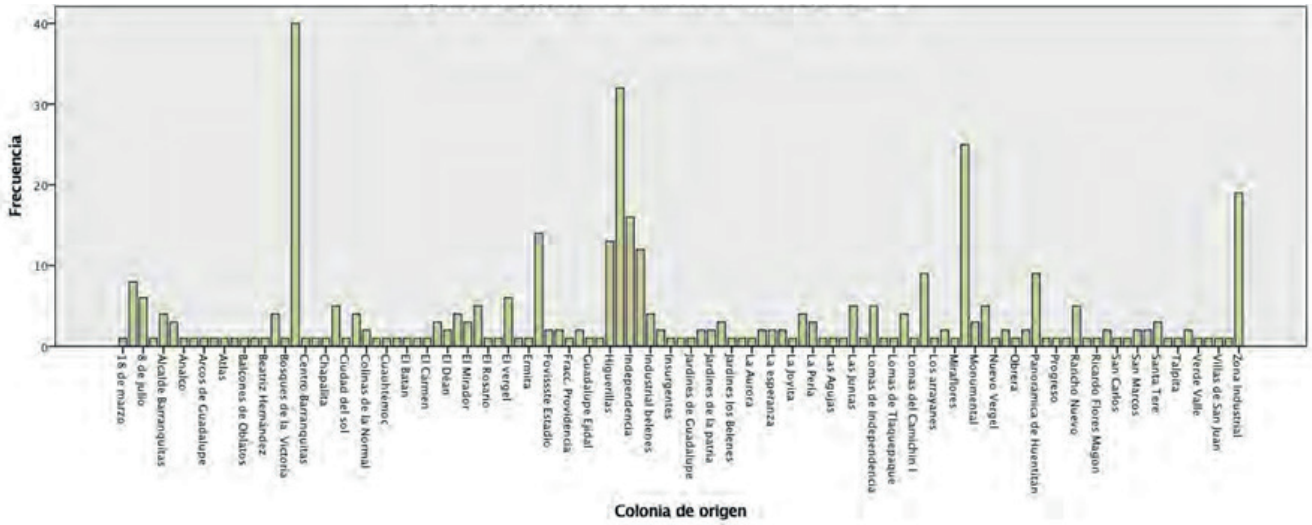


Figure 14. Origin of Macrobús users' trips by neighborhood

Table 4 shows that the top 10 neighborhoods in Guadalajara that attract trips by Macrobús users are: Colonia Centro with 22,26 % of trips, Huentitán el bajo with 13,23 %, Miravalle (Guadalajara section) with 5,16 %, Independencia with 4,52 %, Lomas del Paraíso with 4,19 %, Zona Industrial with 3,87 %, Independencia Ote. with 2,90 %, Monumental with 2,90 %, Lomas de Independencia with 2,58 %, Panorámica de Huentitán with 2,58 %, and 35,8 % distributed among the other neighborhoods of Guadalajara surrounding the corridor.

Table 4. Travel destinations by neighborhood in Guadalajara

Neighborhood	Percentage	Destination of travel by neighborhoods	Percentage	Neighborhood of Guadalajara	Percentage
Downtown	22	Central area	0,9	Atlas	0,32
Huentitán el bajo	13,2	Americana	0,65	Drive-in	0,32
Miravalle	5,16	Artisans	0,65	Benito Juárez	0,32
Independence	4,5	Barragán y Hernández	0,65	Chapalita	0
Lomas del Paraíso	4,1	El Manantial	0,65	Belisario District	0,3
Industrial Zone	3,8	El Retiro	0,65	Echeverría	0,32
Independencia East	2,9	El Sauz	0,65	East Guadalajara	0,32
Monumental	2,9	Fovissste Stadium	0	Mayor's Gardens	0,32
Lomas de Independencia	2,5	La Perla	0	Jardines de la Paz	0
Panoramic view of Huentitán	2,58	Ladrón de Guevara	0	Country Gardens	0,32
Railway	2,26	Mexicaltzingo	0,65	Jasdines de la Cruz	0
Mayor Barranquitas	1,29	Morelos	0,65	La Aurora	0,32
Higuerillas	1,29	Providencia	0,65	La Cruz	0,32
Infonavit Stadium	1,29	Rincón del Agua Azul	0,65	La Federacha	0,32
Oblatos	1,29	San Andrés	0,65	Lafayette	0,32
Olimpica	1,29	San Juan de Dios	0,65	Miguel Hidalgo	0
Colinas de la Normal	0,9	Villa Hermosa	0	Polanco	0
Huentitán el Alto	0,97	May 1	0,32	Quinta Velarde	0,32
La Esperanza	0,97	May 5	0,32	San Antonio	0,32
La Nogalera	0,97	July 8	0,32	San Marcos	0,32
Moderna	0,97	Aaron Joaquin	0,32	Santa Tere	0,32
Ricardo Flores Magón	0,97	Analco	0,32	Vallarta Poniente	0,32
Santa Cecilia	0,97	Arcos Vallarta	0,32		

For the municipality of Zapopan, the five main neighborhoods attracting travelers are: Industrial Belenes, Centro, Arenales Tapatíos, El Colli, and La Tuzanía (table 5). Similarly, for Tlaquepaque, the five main neighborhoods attracting travelers are: Miravalle, Las Juntas, Cerro del 4, Guadalupe Ejidal, and Artesanos (figure 15). In Tonalá, the study shows that only two neighborhoods attract travelers using the Macrobús system: Centro and San Gaspar (figure 16).

Thus, for Tlajomulco de Zúñiga (table 5), the five neighborhoods that attract trips for users of the Macrobús system are: Santa Cruz del Valle, Centro, Fraccionamiento San José del Valle, Hacienda Santa Fe, and La Concha (Chulavista). And for El Salto, the following neighborhoods: Las Pintas and Alameda.

Table 5. Travel destinations by neighborhood in Zapopan

Travel destinations by neighborhood in Zapopan	
Neighborhood	**Percentage**
Industrial Belenes	2
Downtown	14,2
Arenales Tapatios	7,14
El Colli	7,14
La Tuzanía	7,14
Residential Valley	7,14
Rinconada de las Azaleas	7,14
Tabachines	7,14
Tesistan	7,14
Villa de Guadalupe	7,14

Destino de viajes por Colonias deTlaquepaque

Colonia	**Porcentaje**
Miravalle	33.33%
Las Juntas	20.83%
Cerro del 4	6.25%
Guadalupe Ejidal	6.25%
Artesanos	4.17%
Centro	4.17%
Lomas del 4	4.17%
Romita	4.17%
El Mirador	2.08%
El Vergel	2.08%
Fovissste Miravalle	2.08%
Las Liebres	2.08%
Lomas de la Victoria	2.08%
San Martín de las flores	2.08%
Santa Cruz de la Loma	2.08%
Toluquilla	2.08%

Figure 15. Travel destinations by neighborhood in Tlaquepaque

Destino de viajes por Colonias de Tonalá

Colonia	**Porcentaje**
Centro	66.67%
San Gaspar	33.33%

Figure 16. Travel destinations by neighborhood in Tonalá

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Destino de viajes por Colonias deTlajomulco	
Colonia	**Porcentaje**
Santa Cruz del Valle	33.33%
Centro	16.67%
Fracc. San José del Valle	16.67%
Hacienda Santa Fé	16.67%
La Concha	16.67%

Figure 17. Travel destinations by neighborhood in Tlajomulco

Destino de viajes por Colonias de El Salto	
Colonia	**Porcentaje**
Las Pintas	66.67%
Alameda	33.33%

Figure 18. Travel destinations by neighborhood in El Salto

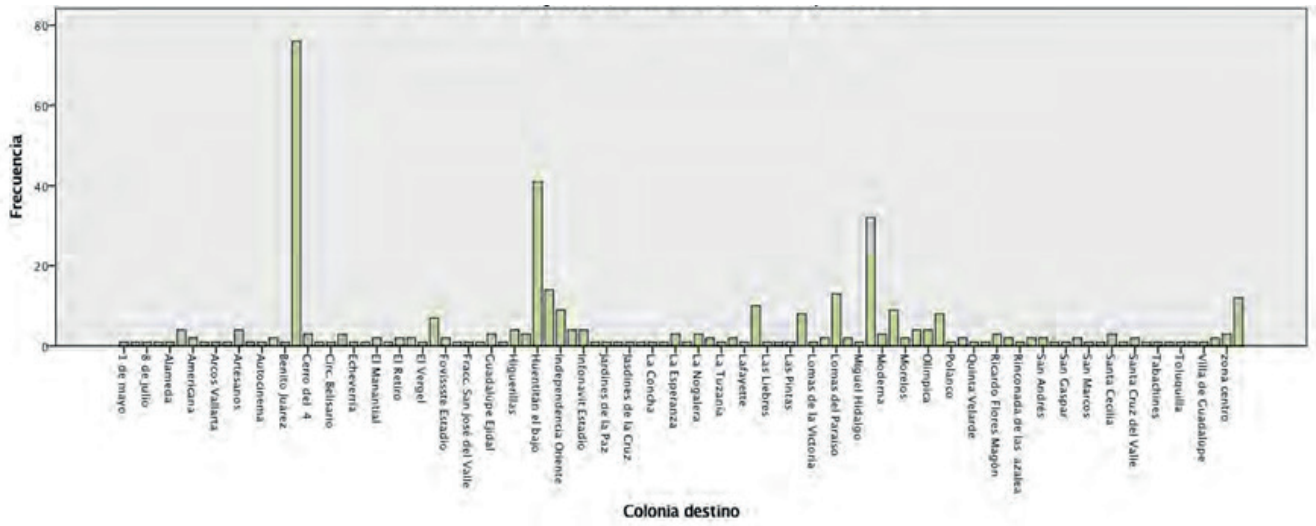

Figure 19. Travel destinations of Macrobús users by neighborhood

			Municipio Destino						
			Guadalajara	Zapopan	Tlaquepaque	Tonalá	Tlajomulco de Zúñiga	El Salto	Total
Municipio Origen	Guadalajara	Recuento	243	12	41	3	6	2	307
		% dentro de municipio de origen	79.2%	3.9%	13.4%	1.0%	2.0%	0.7%	100%
	Zapopan	Recuento	21	0	3	0	0	0	24
		% dentro de municipio de origen	87.5%	0.0%	12.5%	0.0%	0.0%	0.0%	100.0%
	Tlaquepaque	Recuento	35	2	3	0	0	1	41
		% dentro de municipio de origen	85.4%	4.9%	7.3%	0.0%	0.0%	2.4%	100.0%
	Tonalá	Recuento	3	0	1	0	0	0	4
		% dentro de municipio de origen	75.0%	0.0%	25.0%	0.0%	0.0%	0.0%	100.0%
	Tlajomulco de Zúñiga	Recuento	4	0	0	0	0	0	4
		% dentro de municipio de origen	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	El Salto	Recuento	4	0	0	0	0	0	4
		% dentro de municipio de origen	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Total		Recuento	310	14	48	3	6	3	384
		% dentro de municipio de origen	80.7%	3.6%	12.5%	0.8%	1.6%	0.8%	100.0%

Figure 20. Origin-destination matrix by municipality

The origin-destination matrix shows the relationship or intersection between trips from one municipality to another, revealing that Guadalajara is the municipality with the highest number of trips from the other municipalities included in the analysis.

RESULTS

Description of the characteristics of Macrobús users

In accordance with the methodology used in this research project, we present the results obtained from the "Survey of Macrobús Users in the ZMG conducted in 2012" (EMZMG), as well as a description of each product.

Age and gender

The distribution of Macrobús system users by age and gender is described below and shown in figures 21 and 22.

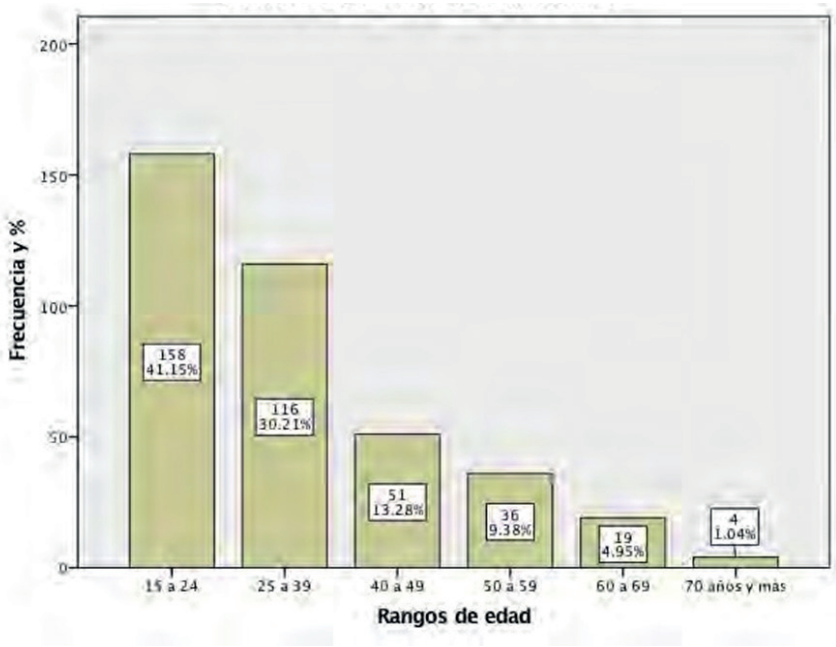

Figure 21. Ages of Macrobús users

It can be seen that young people are the heaviest users of the BRT system, Macrobús, given that it provides public transport in the ZMG to 51 250 users aged between 15 and 25; 37 500 between the ages of 25 and 39, and 16 250 between the ages of 40 and 49, representing 84 % of total trips per day. It also meets the demand of 12 500 people aged 50 to 59, 6250 aged 60 to 69, and 1,250 aged 70 and over, representing 16 % of total daily trips. This demand represents only 5 % of total daily trips on the entire public transportation system in the ZMG.

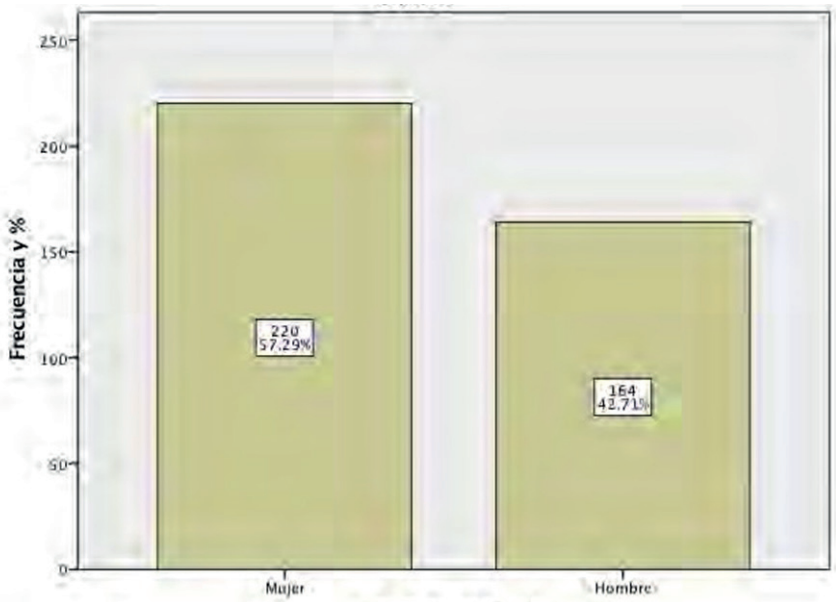

Figure 22. Gender of Macrobús users

In this regard, the highest demand for the BRT system is from women, with 57,3 % of total daily trips, and men, with 42,7 %.

Education, occupation, and income

Considering the level of education of the population using this system, 1950 users have no education, 16 925 have primary education, 26 688 have secondary education, 39 388 have high school education, 39 387 have a bachelor's degree, and only 650 have a postgraduate degree (figure 23).

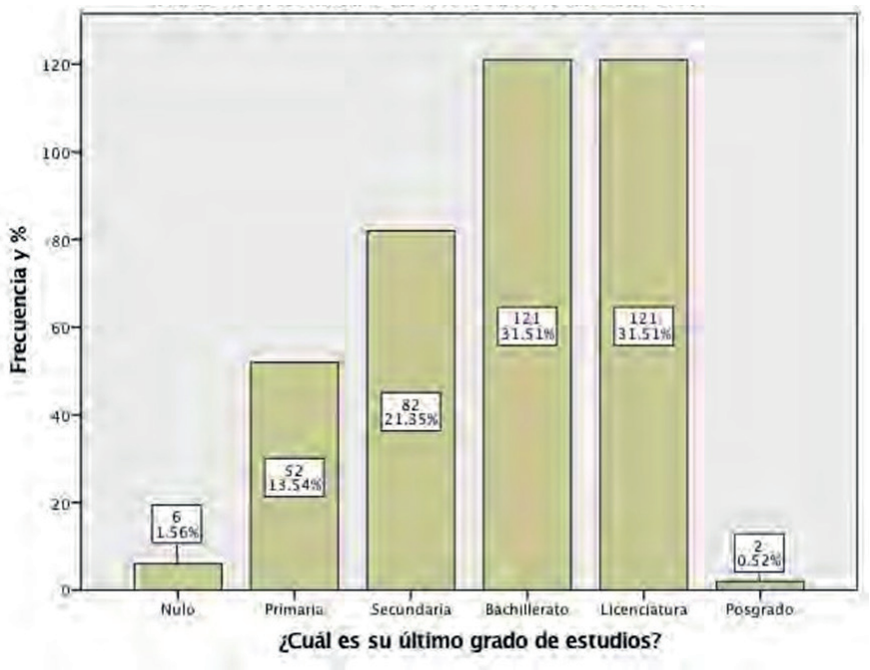

Figure 23. Distribution of Macrobús users by level of education

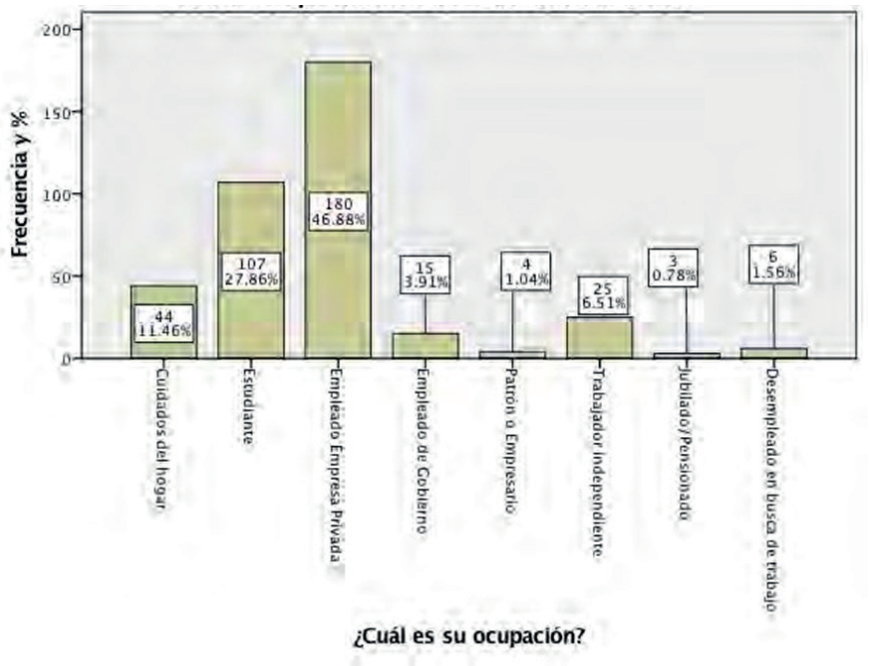

Figure 24. Distribution of Macrobús users by occupation

Macrobús meets the daily demand of 14 325 people who work in domestic care, 34 825 students, 58 600 private company employees, 4888 public servants, 1300 employers or business owners, 8138 self-employed workers, 975 retirees and/or pensioners, and 1950 unemployed people who travel in search of work.

It should be noted that home care workers, students, and employees of private companies and public servants account for 90,11 % of total BRT demand, with the remaining 9,89 % distributed among employers or business owners, self-employed workers, retirees, and unemployed persons. These proportions reflect the

economic activity of the Macrobús corridor and will be described in more detail in the O-D matrix.

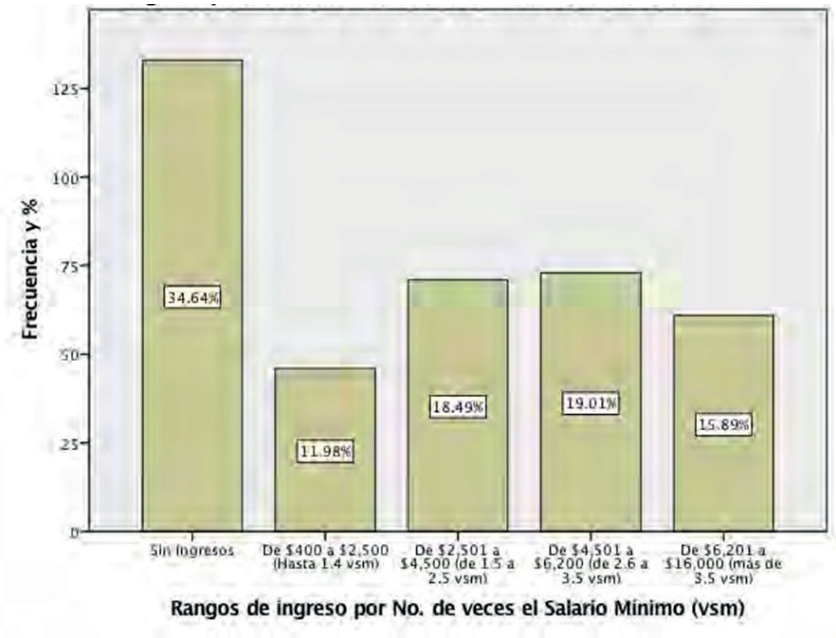

Figure 25. Average monthly income of Macrobús users

Thirty-four point six percent of users have no income and consist of people who are homemakers, unemployed and looking for work, as well as students, representing 43 300 passengers per day. In addition, a large proportion of BRT system users (19,01 %), or 23 763 people, earn between $4501,00 and $6200,00, equivalent to 2,6 to 3,5 times the minimum wage (vsm5); 23,112 users (18,49 %) earn between $2501,00 and $4500,00 pesos (1,5 to 2,5 vsm); 15,89 %, or 19,863 users, report earning between $6201,00 and $16 000,00 pesos on average per month (more than 3,5 vsm).

In this regard, 65,1 % of BRT system users have incomes below 2,5 minimum wages, i.e., below $4500,00 pesos per month on average, and only 15,8 % have incomes above $6201,00 pesos per month on average, reflecting a large gap in user income levels.

Frequency and reasons for O-D travel

Figure 13 shows how frequently Macrobús system users use the service, with 55,7 % of them traveling five days a week. In addition, the frequency of trips on non-working days (Saturday and Sunday) is high, with 6,63 % of users, or 8287 trips on those two days.

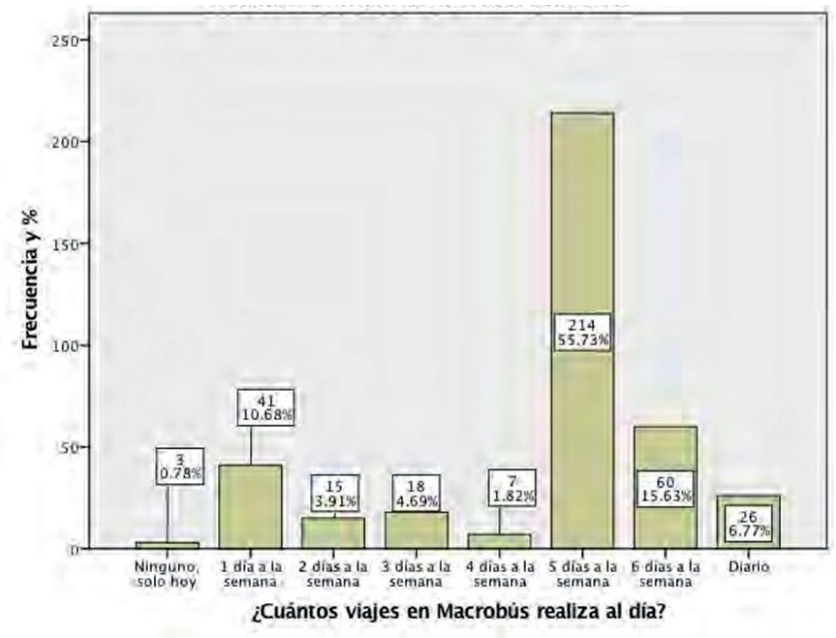

Figure 26. Weekly frequency of use of the Macrobús system

On average, Macrobús users make 10 trips per week. Likewise, half of them make fewer than 10 trips per week and the other half make more than 10 (as indicated by the median). It also shows positive asymmetry and kurtosis, meaning that the data is skewed to the right.

Table 6. Statistics on total trips per week by Macrobús users

N	Valid	384
	Lost	0
Average		9,94
Standard error of the mean		0,273
Median		10,00
Mode		10
Standard deviation		5,348
Variance		28 597
Skewness		0,907
Standard error of skewness		0,125
Kurtosis		2,35
Standard error of kurtosis		0,248
Rank		35
Minimum		1
Max		36
Total		3818
Percentiles	25	6,00
	50	10,00
	75	12

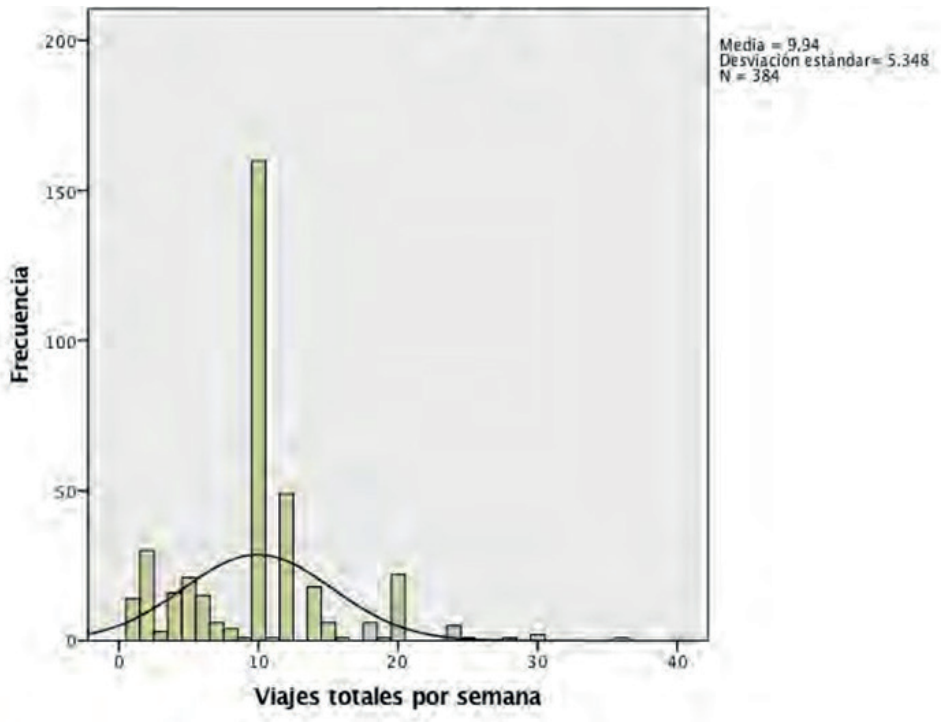

Figure 27. Histogram of total trips per week on Macrobús

Similarly, figure 28 shows that 48,4 % of users make 6 to 10 trips per week from origin to destination, and only 1,3 % of users make 25 to 36 trips. Next, we will describe the reasons for travel from origins and destinations, the municipalities, neighborhoods, and travel matrices of Macrobús users.

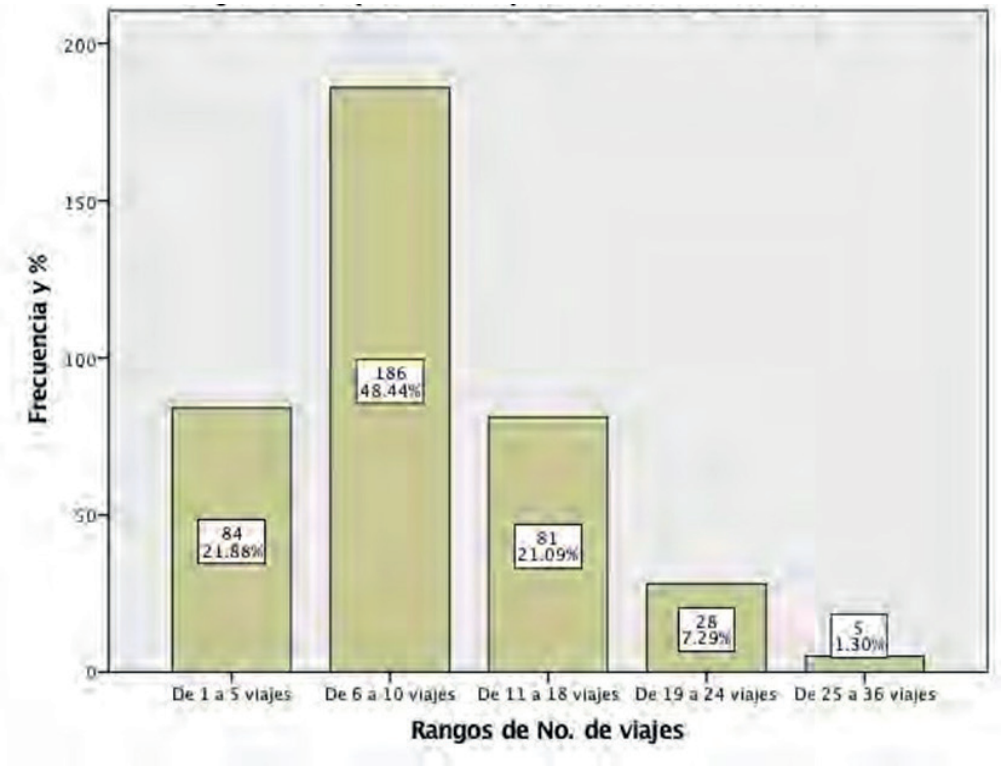

Figure 28. Distribution of trips per week by Macrobús users

Fifty-one point five percent of the reasons for travel by Macrobús users originate in the home, 23,7 % at work, 11,9 % at school, and 12,75 % elsewhere (shopping, entertainment, picking someone up, visiting, or medical services).

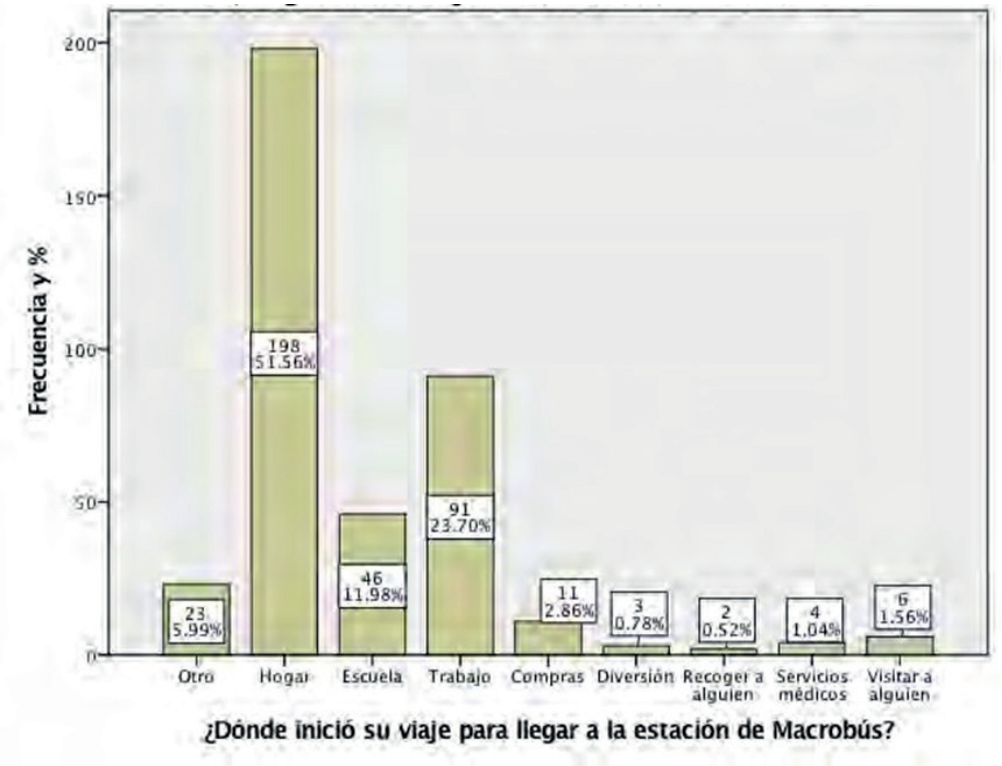

Figure 29. Reason/origin of trips by Macrobús users

In terms of the reason/destination of trips, 38,8 % are to the home, 27,8 % are to work, 13,28 % are to school, and 20,05 % are to other places, which may include shopping, entertainment, picking someone up, visiting, or medical services.

Figure 30. Reason/destination of trips by Macrobús users

It is important to mention that the municipality of Guadalajara is the main generator and attractor of trips by Macrobús system users, accounting for 79,95 % of origins and 80,73 % of destinations, followed by Tlaquepaque with 10,68 % of origins and 12,50 % of destinations, and the rest of the origins and destinations, 9,37 % and 6,77 % for Zapopan, Tonalá, Tlajomulco de Zúñiga, and El Salto.

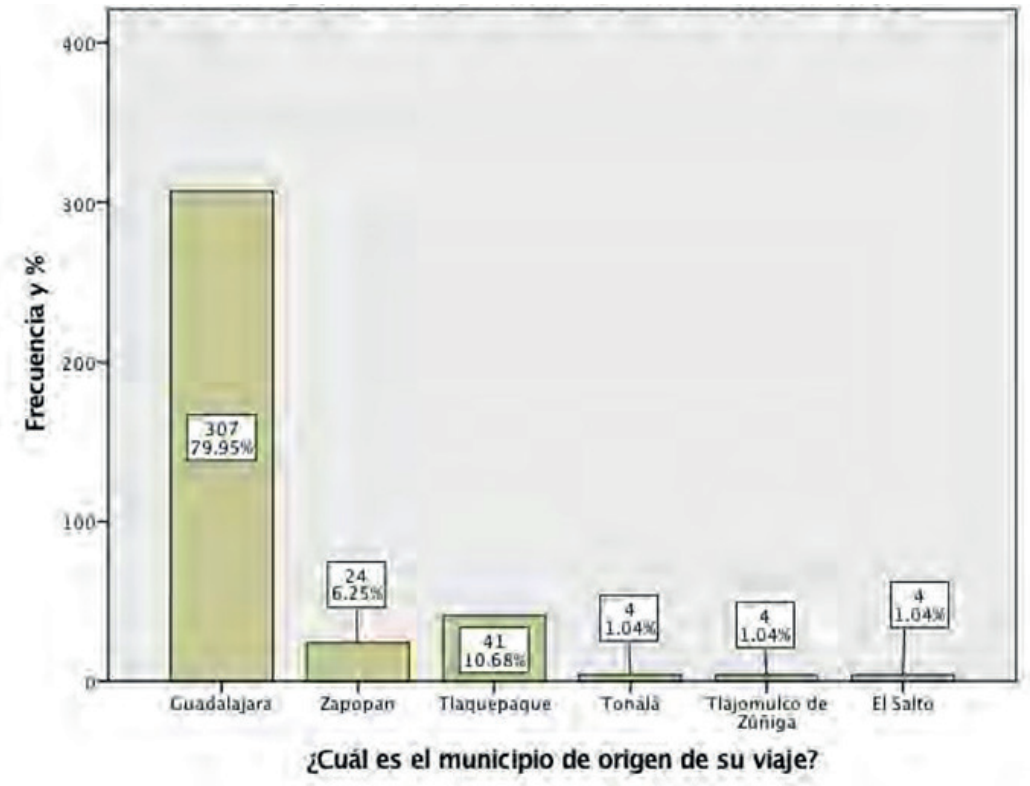

Figure 31. Origin of Macrobús users' trips by municipality

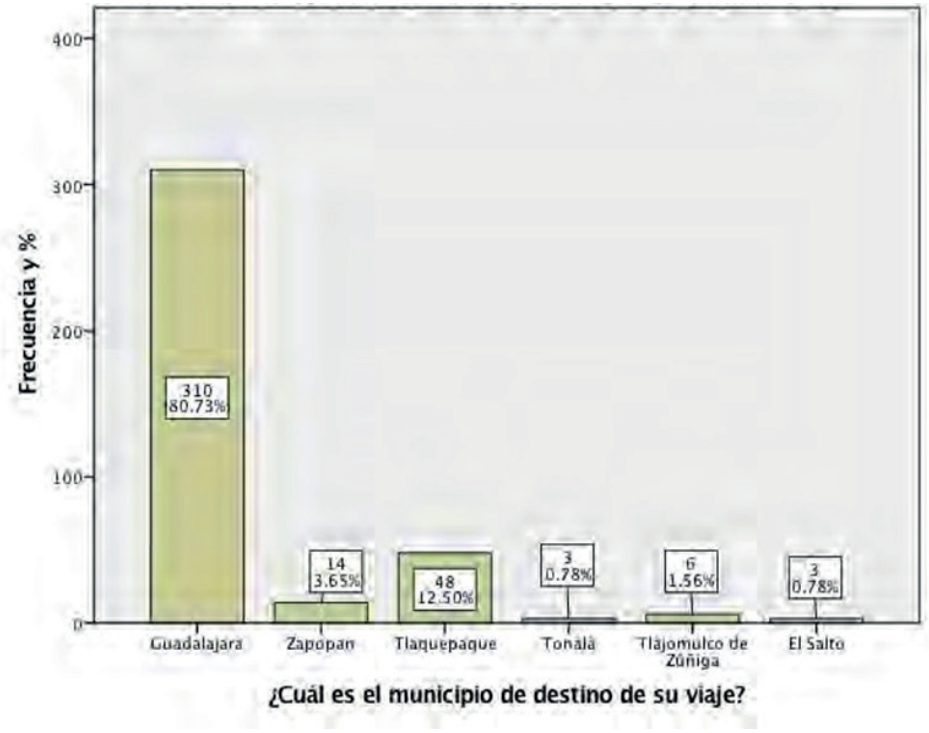

Figure 32. Destination of Macrobús users' trips by municipality

Average travel time

According to the field study, the average total time that Macrobús system users spend on their trips is 00:36:00 minutes, which is a considerable amount of time to travel between origins and destinations in the ZMG. Half of the users spend less than 00:27:00 minutes on their trips and the other half spend more than 00:27:00 minutes, as shown by the median. The most common total travel time was 00:20:00 minutes, and the standard deviation, which shows the dispersion of the data from the mean, was 00:30:00 minutes. The range between the user with the longest travel time and the user with the shortest travel time is 03:53:00 minutes. In addition, the minimum travel time for a user is two minutes, and the person who takes the longest time on a trip is three hours and 56 minutes. Finally, 25 % of users take less than 18 minutes on their journeys, more than 25 % take more than 18 minutes, and 75 % take less than 44 minutes.

Tiempo total de traslado

N	Válido	384
	Perdidos	0
Media		0:36
Error estándar de la media		0:01
Mediana		0:27
Moda		0:20
Desviación estándar		0:30
Varianza		3303263,19
Asimetría		2.576
Error estándar de asimetría		.125
Curtosis		9.509
Error estándar de curtosis		.248
Rango		3:53
Mínimo		0:02
Máximo		3:56
Suma		*****
Percentiles	25	0:18
	50	0:27
	75	0:44

Figure 33. Statistics on the average total travel time of Macrobús users

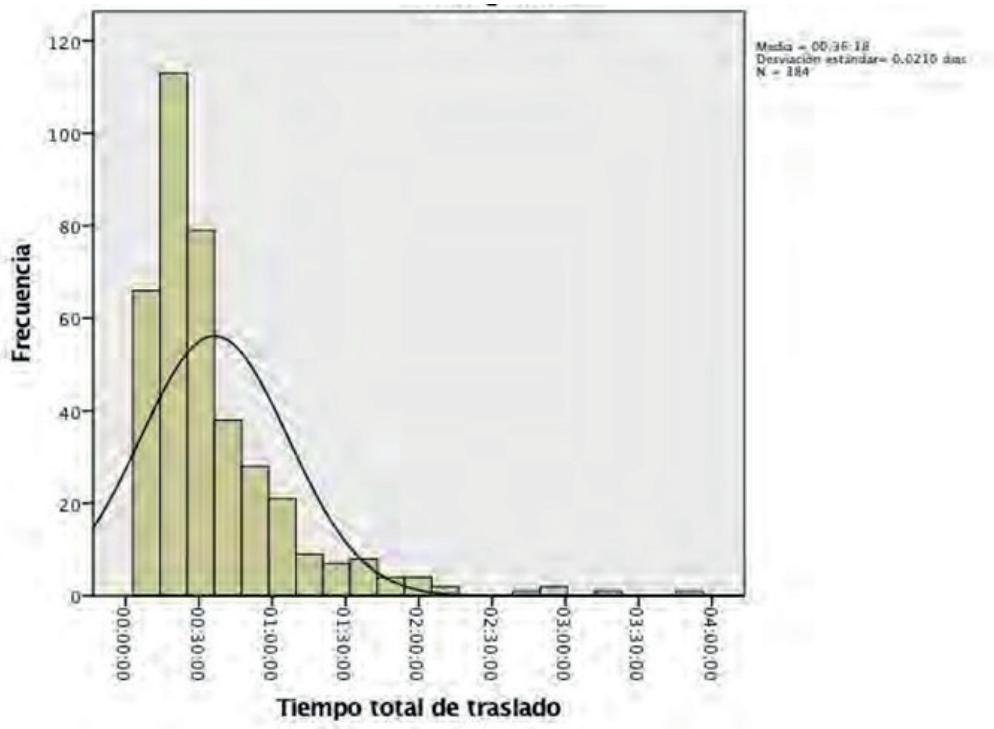

Figure 34. Histogram of total travel time for Macrobús users

Modes of transportation

Figure shows the origin chain of trips made by Macrobús system users. 66,15 % arrive at stations on foot, 22,40 % by public transport, 5,99 % by feeder transport, 3,65 % by private car, 1,56 % by light rail, and only 0,26 % by staff transport.

Similarly, figure shows the destination chain for Macrobús system users, revealing that 66,41 % walk to their final destination, 24,22 % use public transport, 7,55 % use feeder transport, 1,30 % use light rail, and only 0,52 % use private cars.

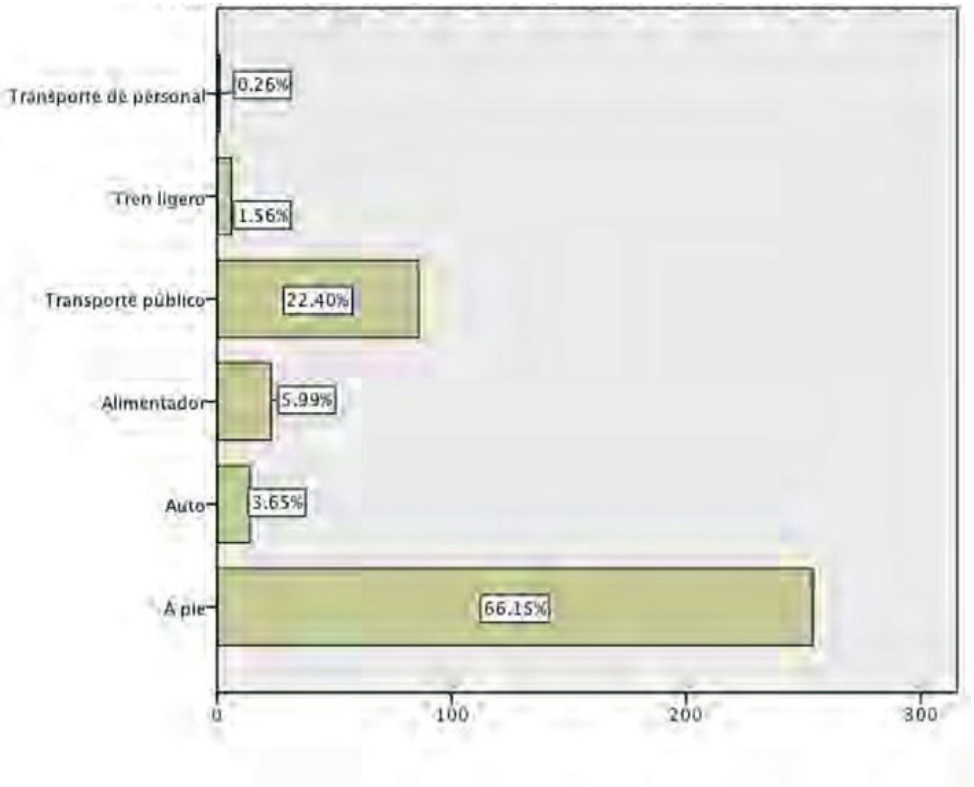

Figure 35. Mode of transportation to reach the Macrobús station

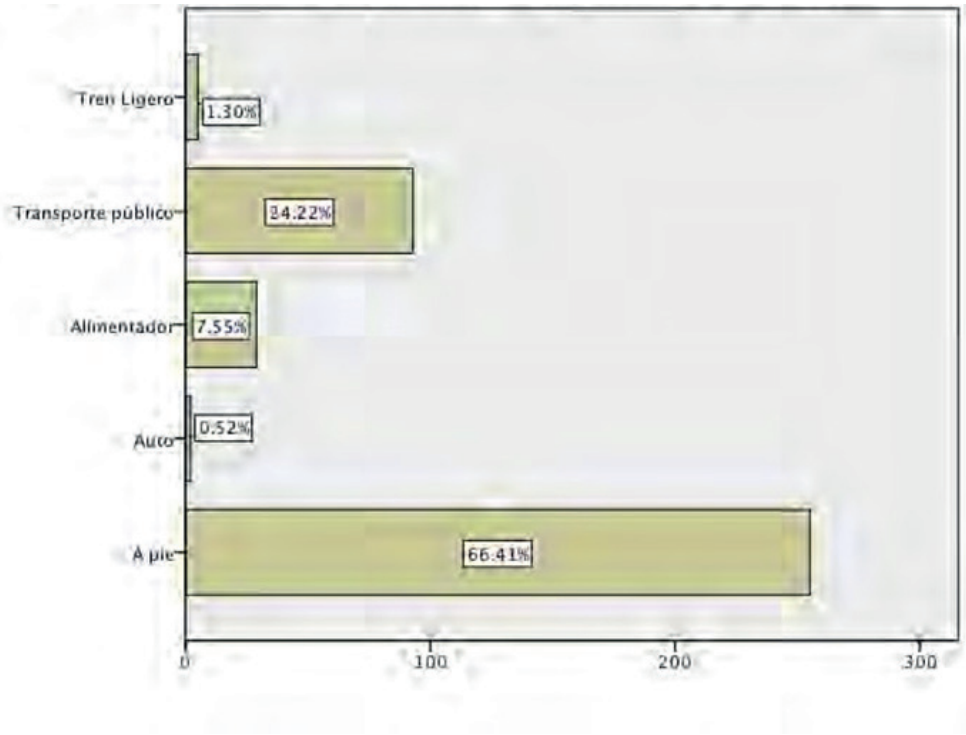

Figure 36. Mode of transportation to reach final destination after Macrobús

Travel cost and user perception

On the other hand, the average total travel cost for users of the Macrobús system is $8,45 pesos, considering Transvales for teachers and students, preferential fare cards (senior citizens, people with disabilities, minors, students, and teachers), light rail transfers, and cash as means of payment, respectively. The current fares during the field survey were as follows:

- Feeder, conventional public transport, light rail, and Macrobús: $6,00 pesos.
- Transfer between feeder, Macrobús, and light rail: $1,00 peso. For example: Feeder ($1,00) + Macrobús ($6,00) = $7,00 pesos or vice versa.
- Transvale or discount card $3,00 pesos.

Half of Macrobús system users pay less than $6,00, while the other half pay more than six pesos. The most common trip cost was $6,00 pesos. In this regard, the range between the user who paid the most and the user who paid the least was $15,00 pesos, with a minimum trip cost of $3,00 and a maximum of $18,00 pesos per trip.

Costo total de traslado

N	Válido	384
	Perdidos	0
Media		8.45
Mediana		6.00
Moda		6
Desviación estándar		3.441
Rango		15
Mínimo		3
Máximo		18
Suma		3243
Percentiles	25	6.00
	50	6.00
	75	12.00

Figure 37. Statistics on the total travel cost of Macrobús users

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Next, we will show users' perceptions of the impact of the Macrobús on their travel times and travel costs. Figure 23 shows that 66,41 % of users said that the implementation of this system reduced their travel time, 12,24 % said it increased their travel time, and 21,35 % said it remained the same, meaning that they continue to spend the same amount of time on their journeys as they did with the conventional transport system that existed on the Calzada Independencia corridor.

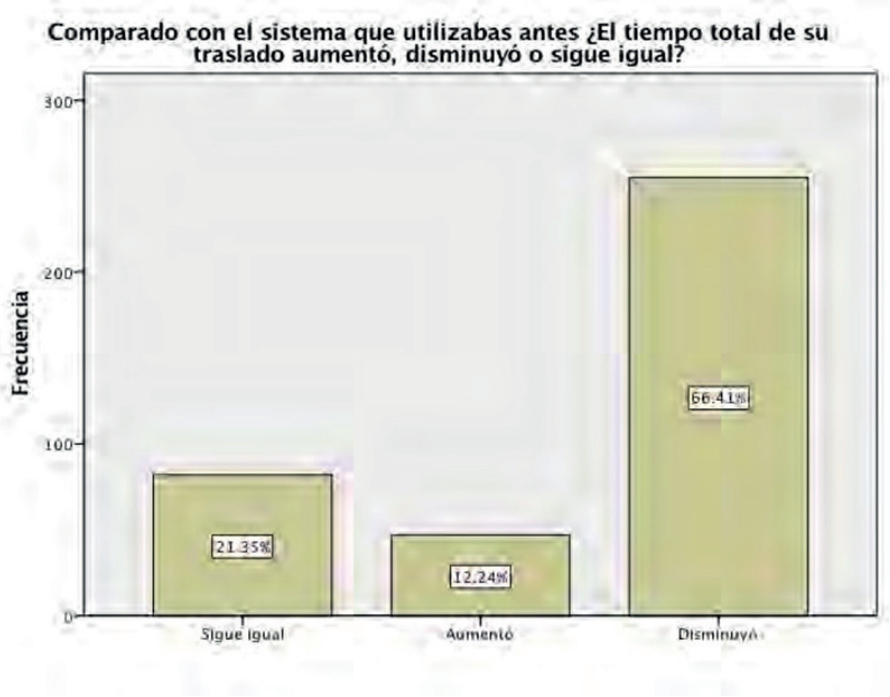

Figure 38. Macrobús users' perception of the change in travel times

Similarly, figure 39 details the perception of Macrobús system users regarding the impact on total origin-destination travel costs when changing transportation systems and shows that 85,16 % perceive that they have benefited from the implementation of this system, because they pay less or the same amount for transportation, while 14,84 % consider that they pay more because they now have to take another form of transportation to reach their destinations.

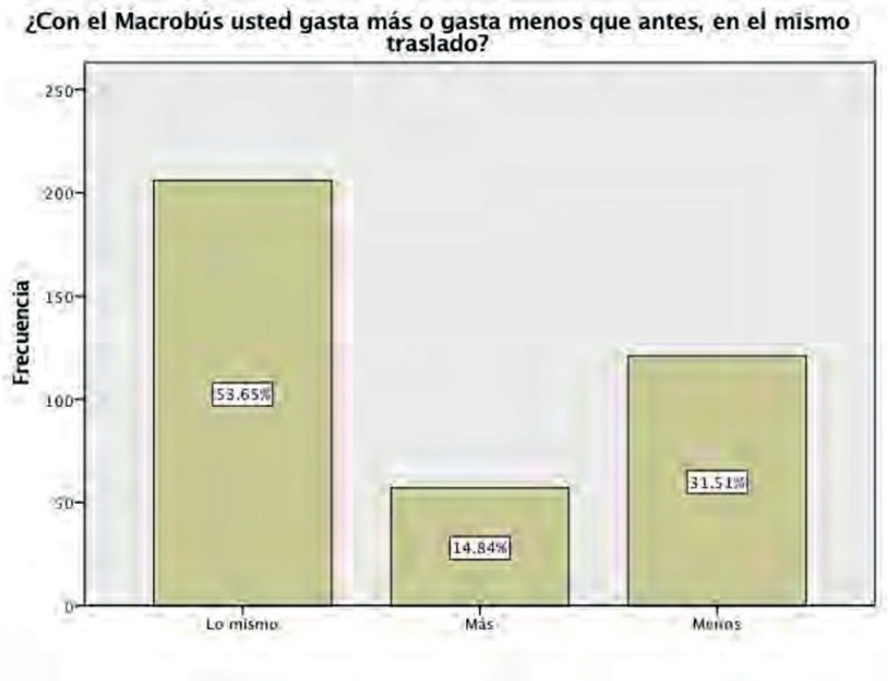

Figure 39. Macrobús users' perception of the change in total travel costs

Analysis of interdependence between variables

To determine the impact of the Macrobús line on total origin-destination travel costs and times, as well as other relevant characteristics of Macrobús users, this section presents an inferential analysis to identify the relationships between individual user characteristics and the daily intensity of trips made using this mode of mass transportation in the ZMG. This will be done by calculating the variable called daily Macrobús user in three categories: low, medium, and high frequency users. To this end, these relationships will be visualized using contingency tables with the SPSS statistical package.

In addition, the degree of association between the variables will be reviewed by applying the Chi-square analysis (with at least 10 % significance) between them and determining whether there is interdependence. These variables are: daily Macrobús user, gender, age, occupation, education, average monthly income, total cost of travel, total travel time, user's perception of total travel time, user's perception of total travel cost, number of transfers at origin, and number of transfers at destination.

Next, we will analyze the interdependence of the variable daily Macrobús user and the gender of users, with the aim of determining which gender uses the BRT more and with what frequency.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Sexo	Mujer	Recuento	56	103	61	220
		% dentro de Sexo	25.5%	46.8%	27.7%	100.0%
	Hombre	Recuento	28	83	53	164
		% dentro de Sexo	17.1%	50.6%	32.3%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Sexo	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	3.963[a]	2	.138

Figure 40. Chi-square analysis between frequency and gender of users

The results shown in figure 40 indicate that although women generally use the Macrobús less frequently, this is not sufficient to statistically confirm an association between the gender of users and the frequency with which they use the Macrobús, with a confidence level of at least 90 % probability. This means that women need transportation as much as men due to their daily needs outside the home.

From the above result, with a significance level of 10 % with 2 degrees of freedom (df) and according to the chi-square value table, we have a critical value of 4,605. The analysis performed yields a calculated chi-square value of 3,963. We can therefore conclude from the interdependence hypothesis test that there is no association between variations in user frequency and gender.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Edad	15 a 24	Recuento	28	89	41	158
		% dentro de Edad	17.7%	56.3%	25.9%	100.0%
	25 a 39	Recuento	31	47	38	116
		% dentro de Edad	26.7%	40.5%	32.8%	100.0%
	40 a 49	Recuento	13	20	18	51
		% dentro de Edad	25.5%	39.2%	35.3%	100.0%
	50 y más	Recuento	12	30	17	59
		% dentro de Edad	20.3%	50.8%	28.8%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Edad	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	9.029[a]	6	.172

Figure 41. Chi-square analysis between frequency and age of users

The result shown in figure 41 indicates that although users aged 25 to 39 generally use the Macrobús infrequently, those aged 15 to 24 use it with medium frequency, and those aged 40 to 49 use it with high frequency, this is not sufficient to statistically confirm an association between user age and the frequency with which they use the Macrobús, with a confidence level of at least 90 % probability. This means that regardless of the age of users, they all require transportation due to other individual daily needs.

The significance indicators are 10 % with 6 gl, the critical value of the chi-square table is 10,645, and the calculated value is 9,029, so the hypothesis of interdependence between the two variables is rejected because there is no association between the two variables.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Ocupación	Cuidados del hogar	Recuento	21	15	8	44
		% dentro de Ocupación	47.7%	34.1%	18.2%	100.0%
	Estudiante	Recuento	18	63	26	107
		% dentro de Ocupación	16.8%	58.9%	24.3%	100.0%
	Empleado	Recuento	36	87	72	195
		% dentro de Ocupación	18.5%	44.6%	36.9%	100.0%
	Patrón, autoempleado y otros	Recuento	9	21	8	38
		% dentro de Ocupación	23.7%	55.3%	21.1%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Ocupación	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	28.421[a]	6	.000

Figure 42. Chi-square analysis between frequency and user occupation

The analysis of daily Macrobús users and occupation indicates that low-frequency users are people who are engaged in housekeeping (compared to other occupations), medium-frequency users are students (compared to other occupations), and high-frequency users are employees (compared to other occupations). However, given the significance indicators (10 %) and chi-square causality (6 gl), there is a certain association in the variations, since the chi-square distribution parameter is 10,645 in its critical value and the calculated value is 28,421, so the hypothesis of interdependence between the two variables is accepted.

This means that, given the occupation of the users, there is at least a 90 % confidence level of probability that there is a classification of the frequency of use of the Macrobús system, which is sufficient to statistically confirm a relationship of association.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Escolaridad	Nulo	Recuento	2	3	1	6
		% dentro de Escolaridad	33.3%	50.0%	16.7%	100.0%
	Primaria	Recuento	10	29	13	52
		% dentro de Escolaridad	19.2%	55.8%	25.0%	100.0%
	Secundaria	Recuento	23	30	29	82
		% dentro de Escolaridad	28.0%	36.6%	35.4%	100.0%
	Bachillerato	Recuento	28	59	34	121
		% dentro de Escolaridad	23.1%	48.8%	28.1%	100.0%
	Profesional	Recuento	21	65	37	123
		% dentro de Escolaridad	17.1%	52.8%	30.1%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Escolaridad	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	8.522[a]	8	.384

Figure 43. Chi-square analysis between frequency and education level of users

The analysis in figure 43 indicates that although users with no schooling generally use the Macrobús less frequently, those with primary education are medium-frequency users and those with secondary education are high-frequency users. This is not sufficient to statistically confirm an association between users' education level and the frequency with which they use the Macrobús, with a confidence level of at least 90 % probability. This means that users without education need to travel as much as those with education, due to their daily needs and their respective reasons for traveling.

The above, with a significance of 10 %, 8 gl and a calculated chi-square value of 8,522 (critical value 13,362), therefore rejects the hypothesis of interdependence between these two variables.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Ingreso	Sin ingresos	Recuento	37	79	17	133
		% dentro de Ingreso	27.8%	59.4%	12.8%	100.0%
	De $400 a $2,500 (Hasta 1.4 vsm)	Recuento	8	19	19	46
		% dentro de Ingreso	17.4%	41.3%	41.3%	100.0%
	De $2,501 a $4,500 (de 1.5 a 2.5 vsm)	Recuento	13	26	32	71
		% dentro de Ingreso	18.3%	36.6%	45.1%	100.0%
	De $4,501 a $6,200 (de 2.6 a 3.5 vsm)	Recuento	16	29	28	73
		% dentro de Ingreso	21.9%	39.7%	38.4%	100.0%
	De $6,201 a $16,000 (más de 3.5 vsm)	Recuento	10	33	18	61
		% dentro de Ingreso	16.4%	54.1%	29.5%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Ingreso	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	33.601[a]	8	.000

Figure 44. Chi-square analysis between frequency and average monthly income of users

Next, the analysis of the variables daily Macrobús users and average monthly income shows that low- and medium-frequency users are passengers with no income (compared to those who do have income), and high-frequency users are those with incomes more than 3,5 times the minimum wage (compared to those with other income levels). This means that given a level of user income, there is at least a 90 % confidence level of probability for a classification of the frequency of use of the Macrobús system, which is sufficient to statistically confirm an association. In this sense, the chi-square test with 10 % significance and 8 degrees of freedom was acceptable because the calculated value is 33,60 and the critical value is 13,362, which is within the acceptance range of the hypothesis of interdependence between the two variables.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Costo total de traslado	De $3.00 a $6.00	Recuento	51	91	54	196
		% dentro de Costo total de traslado	26.0%	46.4%	27.6%	100.0%
	De $7.00 a $11.00	Recuento	8	27	19	54
		% dentro de Costo total de traslado	14.8%	50.0%	35.2%	100.0%
	De $12.00 a $18.00	Recuento	25	68	41	134
		% dentro de Costo total de traslado	18.7%	50.7%	30.6%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Costo total de traslado	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	4.631[a]	4	.327

Figure 45. Chi-square analysis between frequency and total cost of transportation for users

The result shown in figure 45 indicates that although users who pay between $3,00 and $6,00 (compared to those who pay a different amount) are infrequent users, those who pay between $12,00 and $18,00 pesos (compared to those who pay a different price) are medium-frequency users, and those who pay between $7,00 and $11,00 (compared to those who pay other amounts) are high frequency users, it is not sufficient to statistically confirm an association between total transportation cost and frequency of Macrobús use with at least 90 % probability. This means that those who pay between 3 and 6 pesos require transportation as much as those who pay between 7 and 11 pesos and between 12 and 18 pesos.

This cross-tabulation of variables has a 10 % significance with 4 degrees of freedom, and its calculated value from the chi-square table is 4,631, which rejects the hypothesis of interdependence between the two variables because the critical value is 7,779.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Tiempo total de viaje	Bajo (de 00:03 a 00:18 min.)	Recuento	27	65	14	106
		% dentro de Tiempo total de viaje	25.5%	61.3%	13.2%	100.0%
	Medio (de 00: 19 a 00:43 min.)	Recuento	40	71	70	181
		% dentro de Tiempo total de viaje	22.1%	39.2%	38.7%	100.0%
	Alto (más de 00:44 min.)	Recuento	17	50	30	97
		% dentro de Tiempo total de viaje	17.5%	51.5%	30.9%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Tiempo total de viaje	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	23.137[a]	4	.000

Figure 46. Chi-square analysis between frequency and total travel time of users

The result shown in figure 46 indicates that users with a total travel time of 3 to 18 minutes are considered low and medium frequency (compared to those who travel for different lengths of time) and users who travel between 19 and 43 minutes are considered high frequency. This is sufficient to statistically confirm an association between the variables of total travel time and frequency of use of Macrobús with at least 90 % probability.

Given the above, this means that with a 10 % significance level, 4 gl and a calculated chi-square value of 23,137, it is accepted according to the critical parameter of the chi-square table (7,779). In this sense, the hypothesis of interdependence between the two variables is accepted.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Percepción sobre el tiempo total a destino final	Disminuyó	Recuento	59	126	70	255
		% dentro de Percepción sobre el tiempo total a destino final	23.1%	49.4%	27.5%	100.0%
	Sigue igual	Recuento	13	39	30	82
		% dentro de Percepción sobre el tiempo total a destino final	15.9%	47.6%	36.6%	100.0%
	Aumentó	Recuento	12	21	14	47
		% dentro de Percepción sobre el tiempo total a destino final	25.5%	44.7%	29.8%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Percepción sobre el tiempo total a destino final	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	3.776[a]	4	.437

Figure 47. Chi-square analysis between frequency and user perception of total travel time

The result shown in figure 47 indicates that although users who perceive a longer total travel time are low-frequency users, those who perceive a shorter total travel time are medium-frequency users, and those who perceive the same total travel time are high-frequency users. However, this is not sufficient to statistically confirm an association between these variables with at least 90 % probability.

This means that these user perceptions do not impact the frequency of Macrobús use. The above, with 10 % significance, 4 gl, and a calculated chi-square value of 3,776 against a critical value of 7,779, rejects the hypothesis of interdependence between the two variables.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Percepción sobre el costo total de traslado	Menos	Recuento	29	51	41	121
		% dentro de Percepción sobre el costo total de traslado	24.0%	42.1%	33.9%	100.0%
	Lo mismo	Recuento	45	105	56	206
		% dentro de Percepción sobre el costo total de traslado	21.8%	51.0%	27.2%	100.0%
	Más	Recuento	10	30	17	57
		% dentro de Percepción sobre el costo total de traslado	17.5%	52.6%	29.8%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Percepción sobre el costo total de traslado	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	3.352[a]	4	.501

Figure 48. Chi-square analysis between frequency and perception of the total cost of transportation for users

The results shown in figure 48 indicate that although users who perceive lower and higher total transportation costs are low-frequency and high-frequency users, and those who perceive the same cost are medium-frequency users, this is not sufficient to statistically confirm an association between these variables with at least 90 % probability.

This means that these user perceptions do not impact the frequency of Macrobús use. This has a significance of 10 %, 4 gl, and a calculated chi-square value of 3,352 against a critical value of 7,779, therefore rejecting the hypothesis of interdependence between the two variables.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Transbordo origen	Sin transbordo	Recuento	64	135	70	269
		% dentro de Transbordo origen	23.8%	50.2%	26.0%	100.0%
	Transbordo	Recuento	20	51	44	115
		% dentro de Transbordo origen	17.4%	44.3%	38.3%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Transbordo origen	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	6.140[a]	2	.046

Figure 49. Chi-square analysis between frequency and origin of user transfers

The expected relationship between low-frequency users and transfers at origin (compared to those who did not transfer) is 23,8 % more likely, medium-frequency users with transfers (compared to those without) was 44,3 % more likely, and high-frequency users with transfers (compared to those without) was 38,3 % more likely. In this case, given a significance level of 10 % with 2 gl and a calculated value of 6,140 and a critical value of 4,605, the chi-square test is significant, so the hypothesis of interdependence between these two variables is accepted.

			Usuario Cotidiano de Macrobús			
			Usuario de frecuencia baja (1 a 5 viajes)	Usuario de frecuencia media (6 a 10 viajes)	Usuario de frecuencia alta (11 viajes y más)	Total
Transbordo destino	Sin transbordo	Recuento	60	134	63	257
		% dentro de Transbordo destino	23.3%	52.1%	24.5%	100.0%
	Transbordo	Recuento	24	52	51	127
		% dentro de Transbordo destino	18.9%	40.9%	40.2%	100.0%
Total		Recuento	84	186	114	384
		% dentro de Transbordo destino	21.9%	48.4%	29.7%	100.0%

Pruebas de chi-cuadrado

	Valor crítico	Grados de libertad	Nivel de significancia crítico
Chi-cuadrado de Pearson	9.975[a]	2	.007

Figure 50. Chi-square analysis between frequency and users' destination transfers

In the case of the variables daily Macrobús users and origin transfers, the expected relationship between low-frequency users and destination transfers (compared to those without transfers) is 18,9 % more likely, the expected ratio of medium-frequency users with destination transfers (compared to those without) is 40,9 % more likely, and the expected ratio for high-frequency users with destination transfers (compared to those without) is 40,2 % more likely. Thus, with a significance level of 10 %, 2 gl and a calculated chi-square value of 9,975 compared to a critical value of 4,605, the hypothesis of interdependence between the two variables is accepted.

Cruce	Valor crítico	Grados de libertad	Nivel de significancia crítico	Significancia *90% **95% ***99%
Sexo * Frecuencia de uso	3.963	2	0.138	
Edad * Frecuencia de uso	9.029	6	0.172	
Ocupación * Frecuencia de uso	28.421	6	0.000	***
Escolaridad * Frecuencia de uso	8.522	8	0.384	
Ingreso promedio mensual * Frecuencia de uso	33.601	8	0.000	***
Costo total de traslado * Frecuencia de uso	4.631	4	0.327	
Tiempo total de viaje * Frecuencia de uso	23.137	4	0.00	***
Percepción del usuario sobre el tiempo total de viaje * Frecuencia de uso	3.776	4	0.437	
Percepción del usuario sobre el costo total de traslado * Frecuencia de uso	3.352	4	0.501	
Transbordos origen * Frecuencia de uso	6.14	2	0.046	*
Transbordos destino * Frecuencia de uso	9.975	2	0.007	**

Figure 51. Summary of interdependence between variables

In summary, given the significance data from the analysis of the variables: daily Macrobús user, gender, age, occupation, education, average monthly income, total cost of travel, total travel time, user perception of total travel time, user perception of total cost of travel, number of transfers at origin, and number of transfers at destination, the variables with the highest statistical representativeness are occupation, average monthly income, total travel time, number of transfers at origin, and number of transfers at destination. Therefore, we can conclude that the implementation of the BRT system known as Macrobús has a positive impact on the total origin-destination (O-D) travel costs and times for users.

CONCLUSIONS

Based on the methodology used and the results, we can conclude the following: as indicated in section II.5,5 "Travel time savings" and the results of the field survey, 66,41 % of users reduced their travel times, as stated in section IV.1,6 "Travel cost and user perception." Therefore, this information allows us to verify the hypothesis, since there was a favorable impact on travel time for users.

However, if the result mentioned in the previous paragraph were the opposite, i.e., a reduction in average speed, it would not only impact users, but also reduce the system's revenue, increase operating costs, and generate higher levels of pollutant emissions, in addition to reducing the average speed of other users.

Likewise, the results revealed that 65,1 % of users are workers and have incomes below 2,5 minimum wages, i.e., below $4500,00 pesos. This is highly relevant because it allows us to demonstrate the hypothesis. In terms of the impact of the Macrobús system on users' pockets, we concluded that there is minimal impact, as 85,1 % of users perceive a benefit. Of this percentage, 53 % say they have not saved money with the implementation of the Macrobús, but a third of users, or 31 %, have benefited. However, 14,84 % did perceive an increase in costs, and if we add to this figure the 53 % who did not perceive any savings with the implementation of the BRT, there is still a beneficial impact for 68,4 % of users.

In this regard, considering the previous paragraphs, we affirm that public policies are needed to promote multimodal transport so that the BRT system increases the modal factor, given that the results of the study show that 22,40 % arrive at stations by public transport, 5,99 % by feeder transport, 3,65 % by private car, 1,56 % by light rail, and only 0,26 % by staff transport. For example, in addition to the above, the survey found that none of the respondents use bicycles to get to and from stations.

However, despite the fact that 80 % of daily trips made by the population on the Macrobús system are in the municipality of Guadalajara, reflecting the need for a cross-municipal mobility plan to strengthen the guiding principle of public transport and mobility in general, it is necessary to act in a coordinated manner, continue to follow guidelines and regulations, and implement agreements to monitor strategies and programs that promote sustainable multimodal mobility.

Finally, with these general conclusions, it can be seen that the overall objective of the study has been achieved, which was to analyze how the BRT system known as Macrobús impacts the total origin-destination (O-D) travel costs and times of users according to their individual characteristics and the intensity with which they use this means of transportation in the ZMG.

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FINANCING

None.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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