UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ETS INGENIERÍA DE CAMINOS, CANALES Y PUERTOS

MASTER'S DEGREE FINAL PROJECT

Analysis of mobility in the Valencia Metropolitan Area through discrete choice models. Proposal to improve the metropolitan public transport network.

Presented by

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Abstract

This study is based on the fact that the increase of the population over the past decades in Valencia (Spain) has led to an overcrowding of the urban nucleus and to the expansion of its metropolitan region. The public transport network does not grow as fast as the urban area does, so connections between metropolitan municipalities are scarce and the use of the private vehicle is the only option. The objective of this work is to give continuity to the existing urban and suburban mobility plans published by the local authorities of Valencia by developing a statistical tool for the estimation of the demand of new public transport service. For doing so, an analysis of the public transport supply and demand has been made in order to offer an overall vision of the situation of public transport in Valencia. The main conclusion is that it is possible to improve the sustainability of the metropolitan mobility by setting up new public transport services. A tool that a transport company could use to make technical decisions for implementing new bus lines has been built through the estimation of a Logit Model. As a result, we have proposed two new Metrobús lines, estimating the potential demand. The study ends sketching some possible future developments over this line of work.

Abstract

Cette étude est basée sur le fait que l'augmentation de la population au cours des dernières décennies à Valence (Espagne) a conduit à la surpopulation du noyau urbain et à l'expansion de sa région métropolitaine. Le réseau de transport public ne se développe pas aussi rapidement que la ville, de sorte que les liaisons entre les municipalités métropolitaines sont rares et que l'utilisation du véhicule privé est nécessaire. L'objectif de ce travail est de donner une continuité aux plans de mobilité urbaine et suburbaine existants publiés par les autorités locales de Valence en développant un outil statistique pour l'estimation de la demande d'un nouveau service de transport public. Pour ce faire, une analyse de l'offre et de la demande de transports publics a été réalisée afin de donner une vision globale de la situation des transports publics à Valence. La principale conclusion est qu'il est possible d'améliorer la situation de la mobilité métropolitaine en mettant en place de nouveaux services de transport public. Un outil qu'une entreprise de transport pourrait utiliser pour prendre des décisions techniques pour la mise en œuvre de nouvelles lignes de bus a été construit grâce à l'estimation d'un modèle logit. En conséquence, nous avons proposé deux nouvelles lignes de Metrobús, estimant la demande potentielle. L'étude se termine par une esquisse de certains développements futurs possibles dans ce domaine de recherche.

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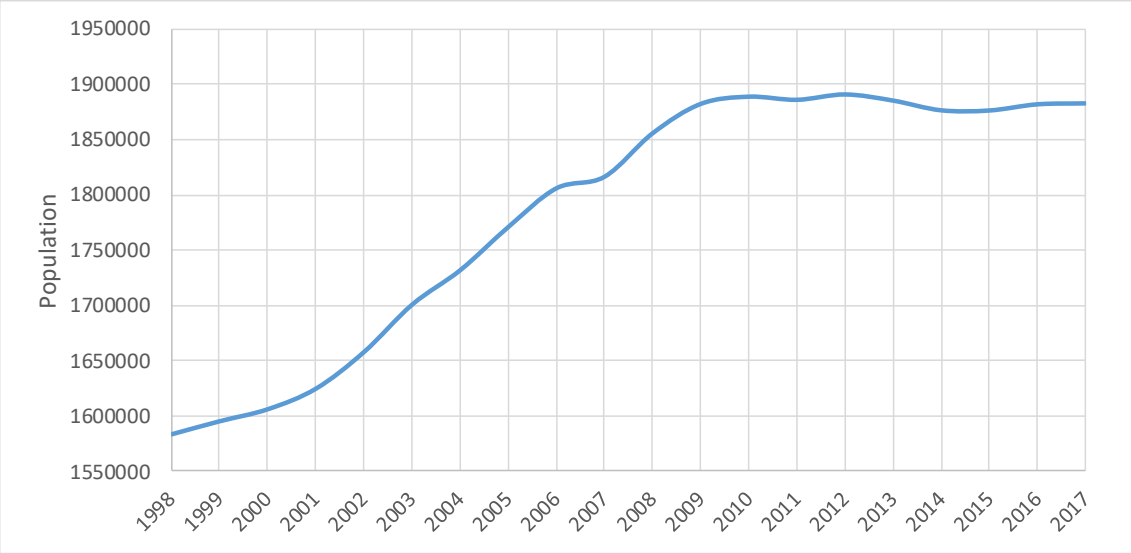
1. Introduction

Main cities in Spain have experienced a great population growth over the past decades. The city of Valencia is not an exception. In the last 20 years, the population of the city and its Metropolitan Area has raised in 300.000 people. The core of the city is overcrowded and the Metropolitan Region is becoming an increasingly south-after option. Graph 1 shows the evolution of the population in Valencia since 1998 until 2017.



Graph 1. Evolution of the population in Valencia.
Source: Own elaboration based on data available at the National Statistics Institute (INE).

These population growth is the source of mobility problems: public transport services are no longer enough to absorb the raising demand, and the transport network is concentrated at the urban centre. There is not a proper public transport network between suburban areas and people tend to use more and more their private vehicle to escape from long travel times, from transfers and from the need of using various transport modes for reaching their destination.

This phenomenon has already been observed in different European cities: Paris is carrying out the biggest public transport project in Europe, the *Grand Paris Express*, aiming to redesign the metropolitan public transportation and to promote a polycentric development through integrated multimodal transport solutions. The *Grand Paris Express* consists in a railway ring connecting peripheral neighbourhoods with the following objectives:

a) Developing rapid transit lines throughout the metropolitan area.
b) Redesigning the habitable space.
c) Reorienting urban expansion in order to rationalize the design and use of public transportation.
d) Creating new mobility patterns by facilitating journeys between suburbs.

At the European Union level, the CIVITAS (acronym for City VITAlity and Sustainability) initiative, based on a set of direct actions in several European cities, should be highlighted. Since its approval in 2002 by the European Commission, several projects have been developed, and around 800 measures have been tested and implemented in 10 thematic areas related to sustainable mobility: car-independent lifestyles, clean fuels and vehicles, collective passenger transport, demand management strategies, spatial planning, mobility management, public involvement, safety and security, transport telematics and urban freight logistics. Within the scope of the plan, which will run until 2020, several research and innovation projects are also defined, including ECCENTRIC, aimed to improving urban transport in terms of resource efficiency, competitiveness of the system, sustainable mobility in suburban districts and urban freight logistics. Its main objectives are related to:

a) Innovative sustainable mobility in peripheric areas, combining new policies, technologies and flexible measures.
b) Innovative urban freight design in urban nucleuses, based on a close cooperation between researchers and the private sector.
c) Contributing to create a data base with effective solutions in specific cities with the aim of replicating these solutions in other places.
d) The promotion of an efficient mobility through networking and the commercial support of projects that are considered successful.

In Valencia, the first steps towards the improvement of mobility were taken thought the publication of the Mobility Plan for the Urban Area of Valencia (PMUS) in 2013. However, it is not until July 2018 when the focus of attention is fixed on the Metropolitan Region of the city with the publication of the Basic Mobility Plan for the Metropolitan Area of Valencia (PMoME). This plan makes a global analysis of mobility and establishes action proposals and initiatives for a more sustainable future in the field of transportation (as the promotion of greener modes of transport: walking, bicycle, public transport, etc.) for the next 12 years at the Metropolitan Region. As the document of the PMoME states, "a city will only have high economic and human development indices if we manage to structure an integrated and efficient transport and mobility system, based on the rational use of the urban space". In addition, it says that "a transport system should be economically, environmentally and socially equilibrated for creating a more competitive and habitable city"[1].

The Mobility Plan for the Metropolitan Area of Valencia is developed together with the Metropolitan Territory Action Plan of Valencia. Jointly, these plans discuss about the future of the territorial and mobility model in order to coordinate both systems for building a sustainable city.

[1] PMoME (2018), Section 1: *Introduction, objectives and background,* page 3.

With the objective of giving continuity to the already implemented plans in the city of Valencia, the aim of the study that reveals this Final Master's Degree Project is to present a detailed analysis of circumferential mobility between suburban nucleuses of Valencia in order to evaluate the need of new public transport services adapted to the new reality of the city, as well as to design a proposal of a new suburban transport network. For doing so, we will begin by exposing the delimitation of the Metropolitan Region of Valencia and how the data was collected (section 2), following with a description of the public transport supply (section 3) and demand (section 4), an analysis of the situation of the mobility in Valencia (section 5), the development of the discrete choice model (section 6) and the application of the results of the model for the implementation of a new suburban bus line (section 7). The study will be finished with a summary of the main conclusions of this work (section 8), a bibliography review (section 0) and an appendices compilation (section 10).

2. Delimitation of the Metropolitan Region of Valencia and data collection

Before proceeding to a more detailed analysis of suburban mobility in the Metropolitan Region of Valencia, it is necessary to determine the municipalities that conform this area. Within the scope of the Basic Mobility Plan for the Metropolitan Area of Valencia (PMoME), the following ones are included (Figure 1, detailed in Figure 2):

1. Alaquàs
2. Albal
3. Albalat dels Sorells
4. Alboraya
5. Albuixech
6. Alcàsser
7. Aldaia
8. Alfafar
9. Alfara del Patriarca
10. Alginet
11. Almàssera
12. Almussafes
13. Benaguasil
14. Benetússer
15. Benifaió
16. Beniparrell
17. Benisanó
18. Bétera
19. Bonrepós i Mirambell
20. Buñol
21. Burjassot
22. Canet d'En Berenguer
23. Carlet
24. Catarroja
25. Cheste
26. Chiva
27. Domeño
28. l'Eliana
29. Emperador
30. Foios
31. Godella
32. Godelleta
33. Llíria
34. Llocnou de la Corona
35. Loriguilla
36. Manises
37. Massalfassar
38. Massamagrell
39. Massanassa
40. Meliana
41. Mislata
42. Moncada
43. Montserrat
44. Museros
45. Nàquera
46. Paiporta
47. Paterna
48. Picanya
49. Picassent
50. Pobla de Farnals
51. la Pobla de Vallbona
52. Puçol
53. el Puig de Santa Maria
54. Quart de Poblet
55. Rafelbunyol
56. Riba-roja de Túria
57. Rocafort
58. Sagunto/ Sagunt
59. San Antonio de Benagéber
60. Sedaví
61. Serra
62. Silla
63. Sollana
64. Sueca
65. Tavernes Blanques
66. Torrent
67. Turís
68. València
69. Vilamarxant
70. Vinalesa
71. Xirivella

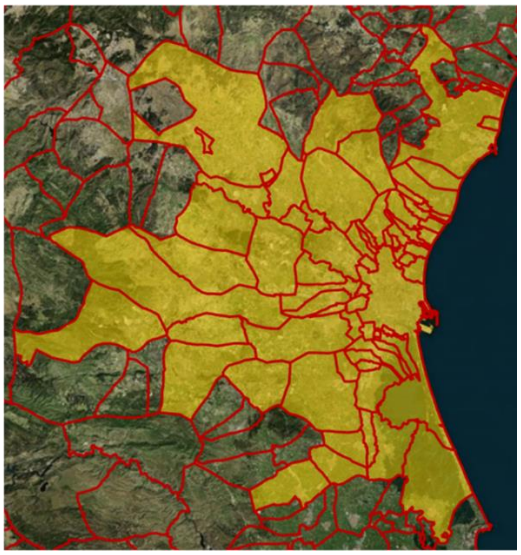


Figure 1. Municipalities integrated in the Metropolitan Area of Valencia within the scope of the PMoME. Source: PMoME (2018).

As it can be observed in the aforementioned figures, there are 71 municipalities that are grouped into four zones: the inner city of Valencia (*casco urbano)*, the *first proximities* to the *casco*

(*continuo urbano*), the *nearest crown* (*primera corona*) and the *furthest crown* (*segunda corona*). Inside this vast region, there are different public transport networks such as the subway, the urban and suburban bus, the suburban railway, the public bicycle system "Valenbisi" or the taxi service. As we will see in next sections of this study, a global analysis of mobility in the whole Metropolitan Region will be made, even though we will focus our attention in a smaller area located at the south-East region between the *first proximities* and the *nearest crown* (Torrent, Paiporta, Picanya, Alfafar, Benetússer, Catarroja, Massanssa and Albal) for the proposal of a new public transport solution.

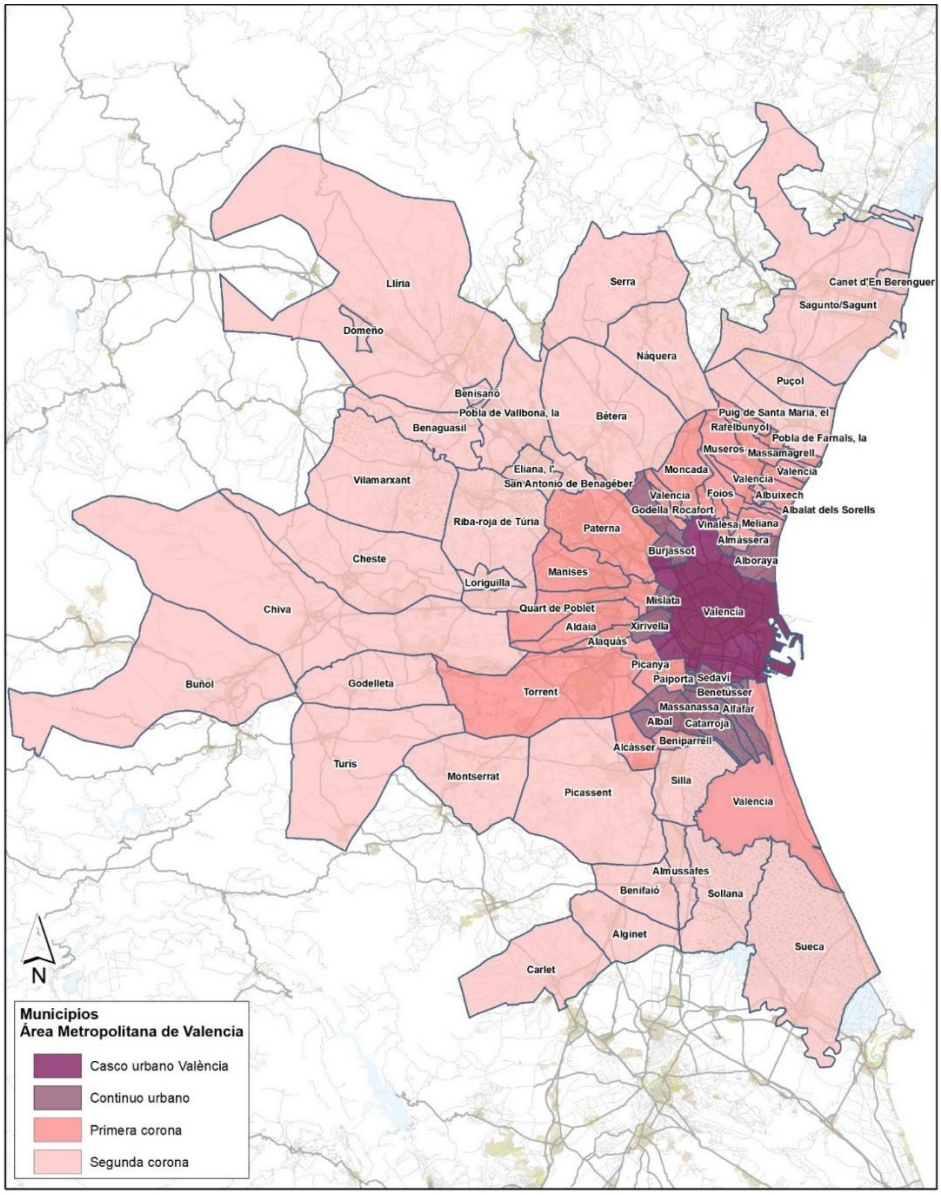


Figure 2. Municipalities integrated in the Metropolitan Area of Valencia within the scope of the PMoME. Source: PMoME (2018).

Regarding the data, the PMoME plan was supported on two data sources: a demographic data-matrix and an urban and interurban displacements/trips data-matrix, which were obtained from a data collection campaign based on a telephone survey[2]. To achieve representative results at the survey, a large number of small *transport zones* were defined based on several criteria described in section 2.3, *Zonificación*, of the PMoME document. Figure 3 shows the location of each transport zone, and Appendix 1 contains the correspondence between the transport zone number and the municipalities.

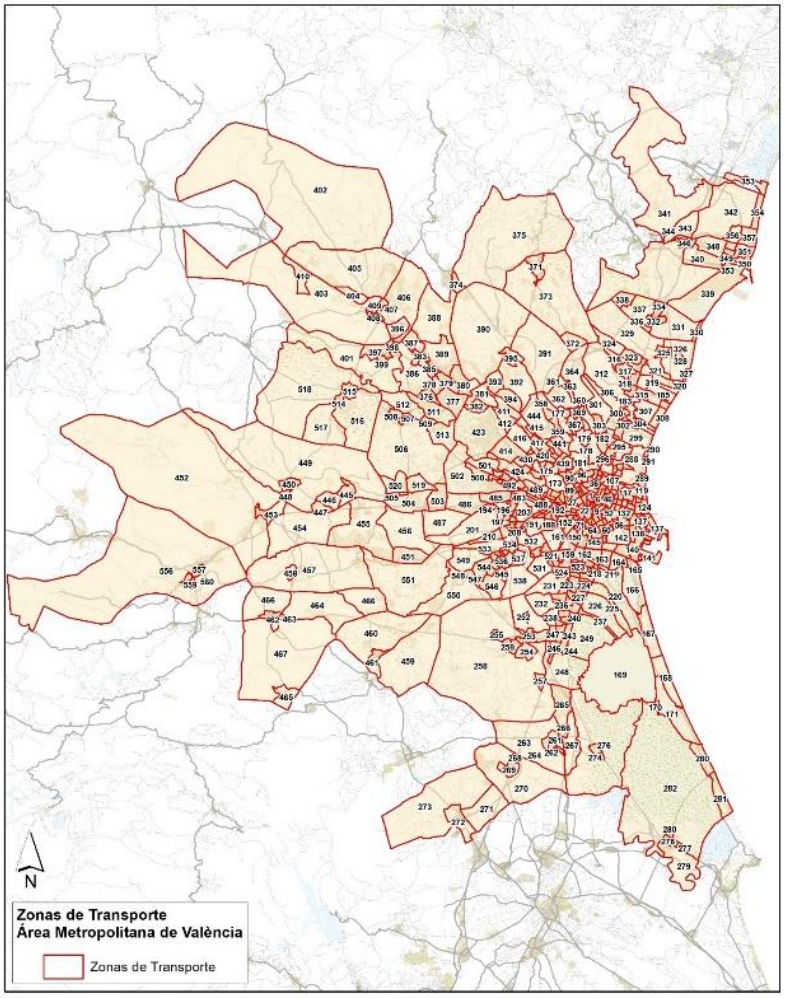


Figure 3. Transport zones defined for the realization of the data collection campaign. Source: PMoME (2018).

[2] The data obtained from this survey has been provided by the company IDOM, which has elaborated the PMoME. It can be consulted at the website of the PMoME (https://www.pmomevalencia.com). IDOM is an independent multinational company that offers professional integrated services in Consulting, Engineering and Architecture around the world (https://www.idom.com/es/).

In each transport zone, the number of surveys that have been made has not been randomly determined; such number, which corresponds to the size of the sample for each zone, has been calculated using the following formula:

$$n = \frac{k^2 \cdot p \cdot q \cdot N}{e^2 \cdot (n-1) + k^2 \cdot p \cdot q} \qquad \text{(Eq. 1)}$$

being:

N: the size of the resident population in the whole of the transport zones.

k: constant that varies according to the level of confidence, which indicates the probability that the obtained result is true. A confidence level of 95,5% is stablished, so the value of the constant is 4,5% and represents the probability that the results will be erroneous.

e: corresponds to the desired sampling error, that is, to the difference between the result obtained after the survey with the used sample and the result obtained in the case that the total population would have been surveyed.

p: determines the proportion of individuals who possess the desired characteristics for the study. This value is normally unknown, and is assumed to be 0,5 (50%).

q: determines the portion of individuals who do not possess the desired characteristics for the study, i.e., 1-p=0,5.

n: corresponds to the size of the sample, that is, the number of surveys to be carried out.

The total number of surveys obtained after applying (Eq. 1) is 19.128, which assure a confidence level of 95% and a sampling error of less than 10% for each of the transport areas. The sampling error for the total sample is 0,72%.

3. Description of the public transport network in Valencia

3.1. Subway network "Metrovalencia"

Managed by Ferrocarrils de la Generalitat Valenciana (FGV), Metrovalencia comprises the subway and tram network of the city of Valencia. FGV manages the passenger transport services and the narrow-gauge infrastructures and tramway lines that run through the Valencian Community.

Figure 4. Metrovalencia train.
Source: https://goo.gl/ZaTbAe.

In the city of Valencia, there are currently six subway lines and three tram lines, making up a total of nine lines covering 156,388 kilometres, of which 129,79 km run on the surface and 26,59 km in tunnels. Figure 5 shows the configuration of the nine subway lines.

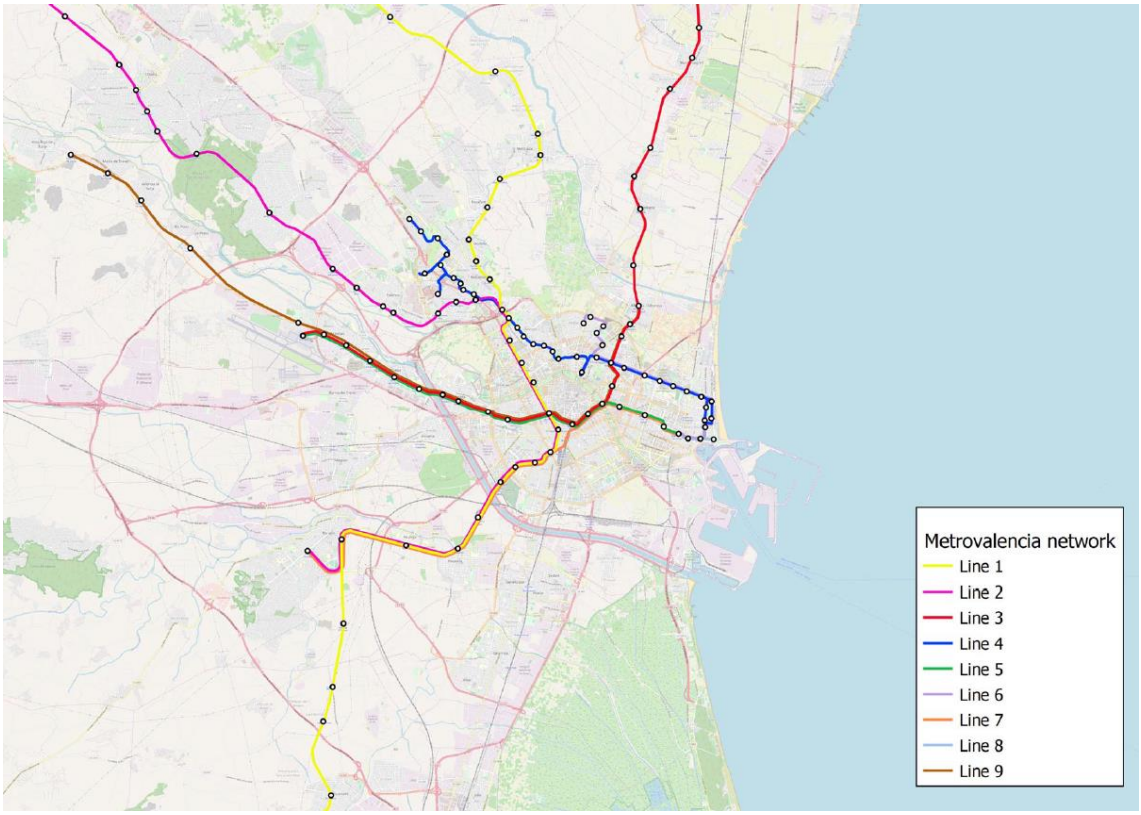


Figure 5. Metrovalencia network.
Source: Own elaboration.

The main characteristics of the network are summarized in Table 1. Tracing a horizontal axis crossing the centre of the city of Valencia, it is obvious that the network is essentially radial and

denser in the northern zone. Later in this study, we will see that the proposal of a new suburban bus line will be located at the southern zone, just where the public transport supply is scarcer.

METROVALENCIA NETWORK						
Line	Kilometres	Number of stations	Number of trains			
			Working days	Non-working days	Saturdays	Holidays
1	72,145 km	40	156	156	110	97
2	39,445 km	33	152	152	108	98
3	24,691 km	26	143	143	107	93
4	16,999 km	33	146	146	112	100
5	13,293 km	18	138	138	98	94
6	3,571 km	21	128	128	100	78
7	15,497 km	16	311	310	290	262
8	1,230 km	4	195	108	105	96
9	24,859 km	23	88	87	79	78

Table 1. Characteristics of Metrovalencia network.
Source: 2017 City Council Statistics Report.

3.2. Urban bus network "EMT Valencia"

The Municipal Transport Company (*Empresa Municipal de Transportes,* EMT), which depends on the City Council of Valencia, operates the urban bus service of Valencia.

According to the information provided at the 2017 Statistics Report published by the City Council of Valencia[3], there are 47 day lines, with two circulating only during summer time, and 13 night lines, conforming a total of 60 lines. EMT Valencia has 480 vehicles that ran 21.163.316 kilometres in 2017 in a total of 1.645.279 hours with an average commercial speed of 12,86 kilometres per hour. Information about the length, commercial speed, travel time, number of buses per day and number of passengers for each line can be found on section 10.1 of this work (Appendix 2).

Figure 6. EMT Valencia bus.
Source: https://goo.gl/opnKKZ.

Figure 7 shows the distribution of the 60 bus lines. Even though EMT Valencia is an urban bus network,

[3] City Council Statistical Office (Oficina de Estadística del Ayuntamiento de Valencia), website: https://www.valencia.es/ayuntamiento/anuario.nsf/fCategoriaVista?readForm&nivel=6_2&Vista=vListadoAnuario&Categoria=Anuario 2017&lang=1&expand=4&subexpandido=5&bdorigen=ayuntamiento/estadistica.nsf

it also connects the city with the municipalities of Alboraya, Alfara del Patriarca, Burjassot, Moncada, Tavernes Blanques, Sueca and Vinalesa.

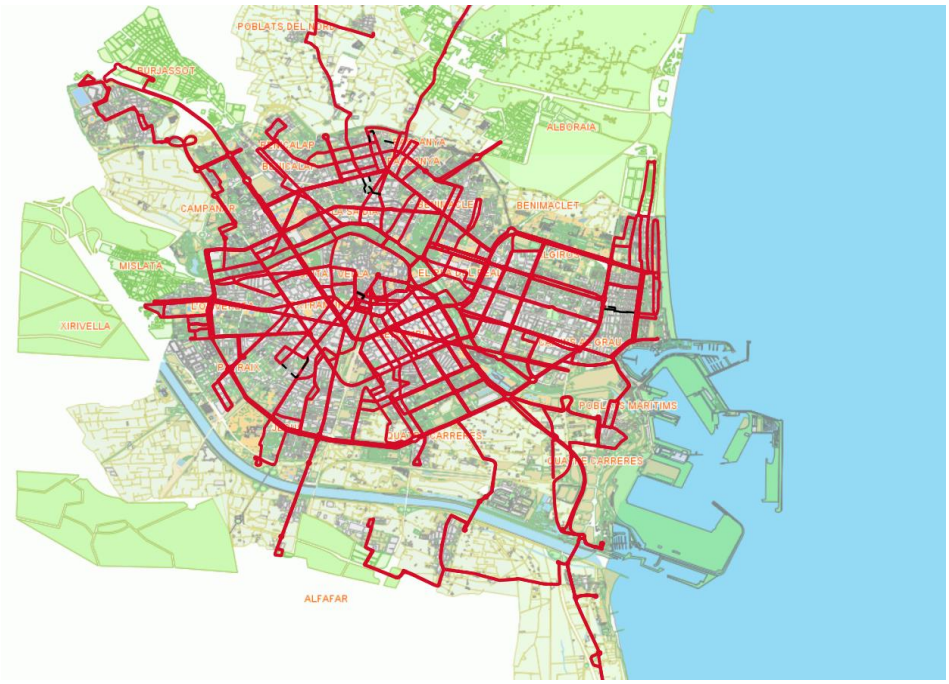


Figure 7. Urban bus network.
Source: www.emtvalencia.es.

3.3. Suburban railway network "Cercanías"

Renfe, which is the Spanish state railway operator[4], provides in Valencia a 252-kilometer suburban railway service divided in six lines. Lines C1, C2 and C5 and C6 begin at the station *Valencia-Estació del Nord*, and lines C3 and C4 begin at the station *València-Saint Isidre*. The routes are summarized in Table 2, and Figure 9 shows the location of the six lines. The configuration of the network is strictly radial from the centre of the city to the North, the South and the West. In addition, it should be noted that some lines share a part of their tracks and get divided at a certain point in the suburban and that line C4 is very short with only two stations. Anecdotally, it can be said that line C1 borders the famous *Albufera* (space of marshes with protected species).

Figure 8. Cercanías train.
Source: https://goo.gl/61GQi8.

[4] *Renfe*: *Red Nacional de Ferrocarriles Españoles*, established in 1941 and now divided in two public entreprises: *Renfe Operadora* and *Administrador de Infraestructuras Ferroviarias* (*ADIF*).

RENFE LINES IN VALENCIA: ROUTES

Line	Stations
C1 – València Nord – Gandía	Valencia Nord, Alfafar-Benetússer, Massanassa, Catarroja, Silla, El Romaní, Sollana, Sueca, Cullera, Tavernes de la Valldigna, Xeraco, Gandia y Platja i Grau de Gandia.
C2 – València Nord – Xàtiva – Moixent	Valencia Nord, Alfafar-Benetússer, Massanassa, Catarroja, Silla, Benifaió-Almussafes, Algemesí, Alzira, Carcaixent, La Pobla Llarga, Manuel-L'Ènova, Xàtiva, L'Alcúdia de Crespins, Montesa, Vallada y Moixent.
C3 – València Sant Isidre – Buñol - Util	València Sant Isidre, Xirivella-Alqueríes, Aldaia, Loriguilla-Reva, Circuit R. Tormo, Cheste, Chiva, Buñol, Venta-Mina, Siete Aguas, El Rebollar, Requena, San Antonio de Requena y Utiel.
C4 – València Sant Isidre – Xirivella L'Alter	València Sant Isidre, Xirivella L'Alter.
C5 – València Nord – Caudiel	Valencia Nord, València-F.S.L., València-Cabanyal, Roca-Cuper, Albuixech, Massalfassar, El Puig, Puçol, Sagunt, Gilet, Estivella-Albalat dels Tarongers, Algimia, Soneja, Segorbe-Ciudad, Segorbe-Arrabal, Navajas, Jérica-Viver y Caudiel.
C6 – València Nord - Castelló	Valencia Nord, València-F.S.L., València-Cabanyal, Roca-Cuper, Albuixech, Massalfassar, El Puig, Puçol, Sagunt, Les Valls, Almenara, La Llosa, Xilxes, Moncofa, Nules-La Vilavella, Burriana-Alquerías N.P., Vila-real, Almassora y Castelló.

Table 2. Characteristics of Cercanías network.
Source: www.renfe.com.

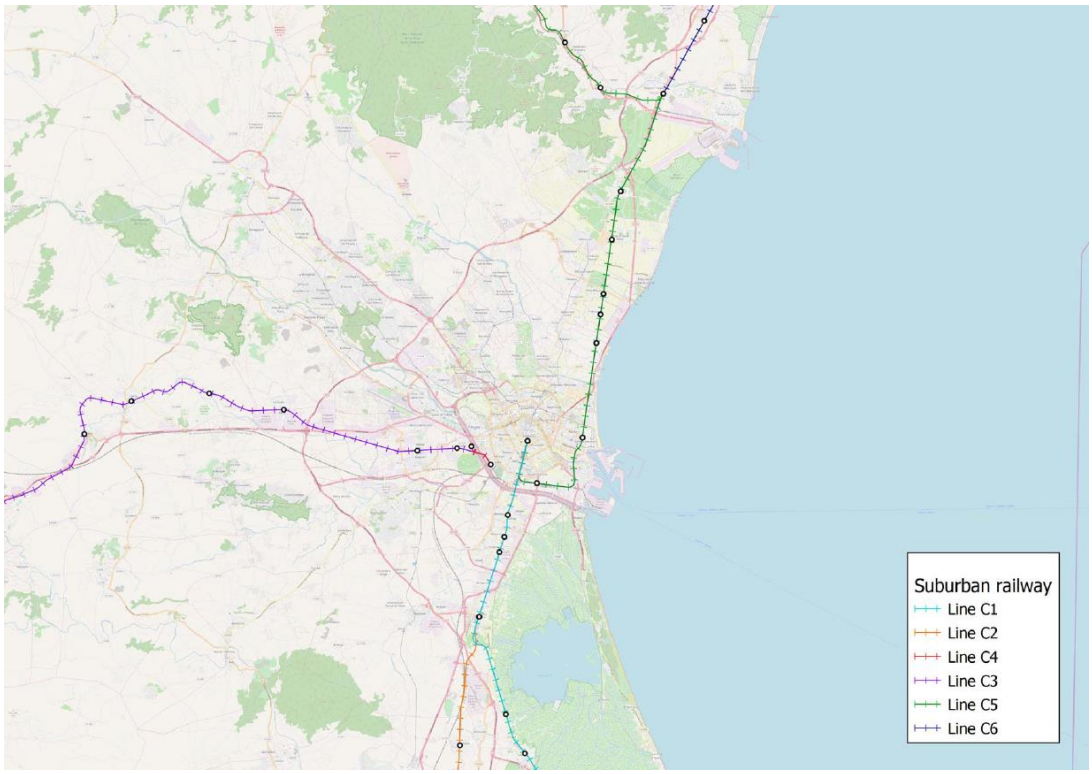


Figure 9. Suburban railway network.
Source: Own elaboration.

3.4. Suburban bus network "Metrobús"

The suburban bus network depends on the local Ministry of Housing, Public Works and Territorial Planning (*Conselleria d'Habitatge, Obres Públiques i Vertebració del Territori*), but it is operated on a concession basis by seven private transport companies (Avsa, Edetania Bus, Urbetur, Autobuses Buñol, Fernanbus, Auvaca and Autocares Herca). The current concession contracts are about to expire and public call for tenders will be soon launched[5], so for the future contracts an improved structure and concession model has been defined, integrating lines in four corridors (shown at Figure 11).

Figure 10. Metrobús vehicle.
Source: https://goo.gl/Z1vWAe.

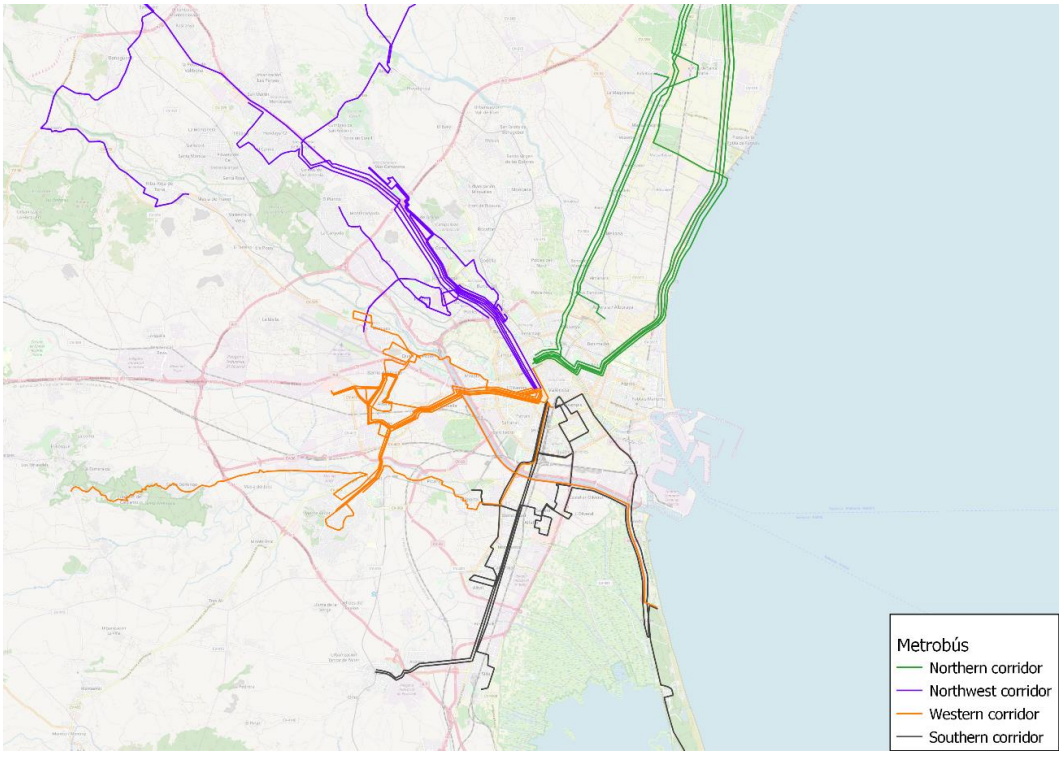


Figure 11. Projected suburban bus "Metrobús" network.
Source: Own elaboration.

The routes followed by the new corridors are next ones:

1) Northern corridor of the Metropolitan Region of Valencia (CV-102): this corridor integrates trips between the Horta Nord municipalities (Albalat dels Sorells, Alboraia, Almàssera, Bonrepòs

[5] According to the European Regulation (CE) nº 1370/2007, the duration of concession contracts for public bus services is limited to 10 years.

i Mirambell, Emperador, Foios, Massalfassar, Massamagrell, Meliana, Museros, La Pobla de Farnals, El Puig, Puçol, Rafelbunyol and Tavernes Blanques), Canet d'En Berenguer (El Camp de Morvedre) and trips between La Vall d'Uixó and Almenara with Valencia and Sagunto.

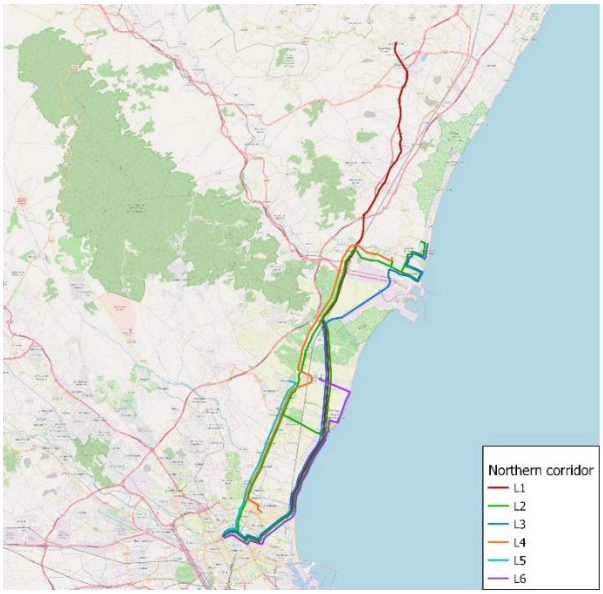


Figure 12. Metrobús lines at the northern corridor. Source: Own elaboration.

2) Northwest corridor of the Metropolitan Region of Valencia (CV-103): this concession integrates trips between the municipalities of Benaguasil, Benissanó, Bétera, Bugarra, Burjassot, Gestalgar, La Pobla de Vallbona, l'Eliana, Llíria, Náquera, Paterna, Pedralba, Riba-roja de Túria, San Antonio de Benagéber, Serra and Vilamarxant and with the city of Valencia.

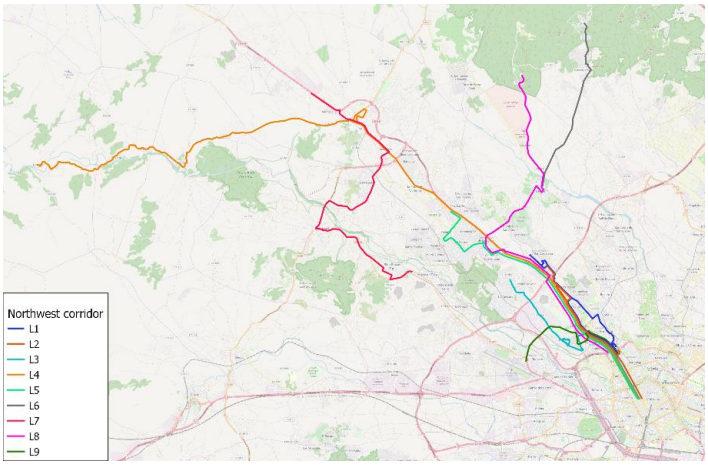


Figure 13. Metrobús lines at the Northwest corridor. Source: Own elaboration.

3) Western corridor of the Metropolitan Region of Valencia (CV-106): this corridor integrates trips between the municipalities of Alaquàs, Aldaia, Calicanto (Chiva), Manises, Mislata, Quart de Poblet, Torrent and Xirivella with Valencia.

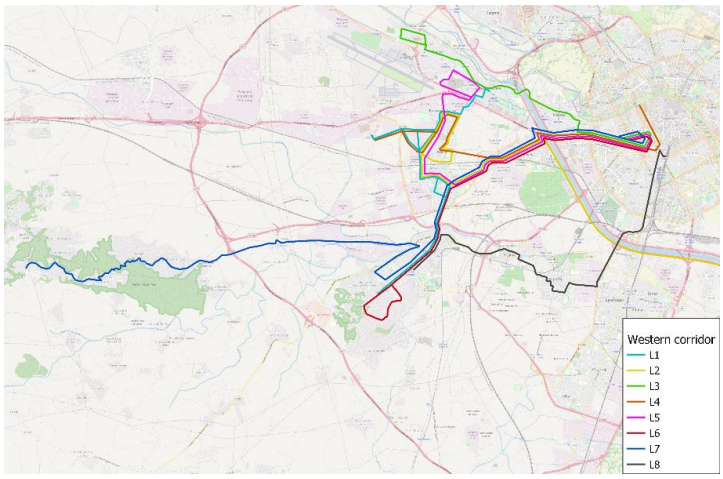


Figure 14. Metrobús lines at the western corridor. Source: Own elaboration.

4) Southern corridor of the Metropolitan Region of Valecia (CV-108): the concession integrates trips between the municipalities of Albal, Alcàsser, Alfafar, Benetússer, Beniparrell, Catarroja, Massanassa, Picassent, Sedaví, Silla, Sueca and Valencia.

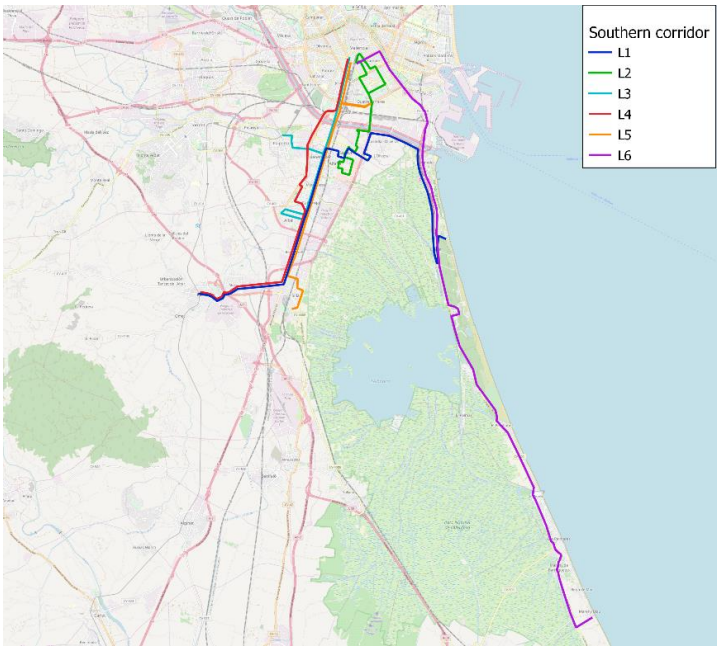


Figure 15. Metrobús lines at the southern corridor. Source: Own elaboration.

3.5. Public bicycle system "Valenbisi"

In June 2010, a public renting bicycle system managed by the company JCDecaux was inaugurated in Valencia. Nowadays, there are 276 stations with 5.502 docks and 2.750 bicycles[6].

Valencia has a very flat surface, so the topology of the city is the optimum for the success of this public transport mode. Figure 17 contains a map where bicycle lanes are represented and where Valenbisi stations are located, and Table 3 shows the number of stations and docks as well as docks per 1.000 inhabitants for each neighbourhood in the city.

Figure 16. Valenbisi station.
Source: https://goo.gl/VfEjZ3.

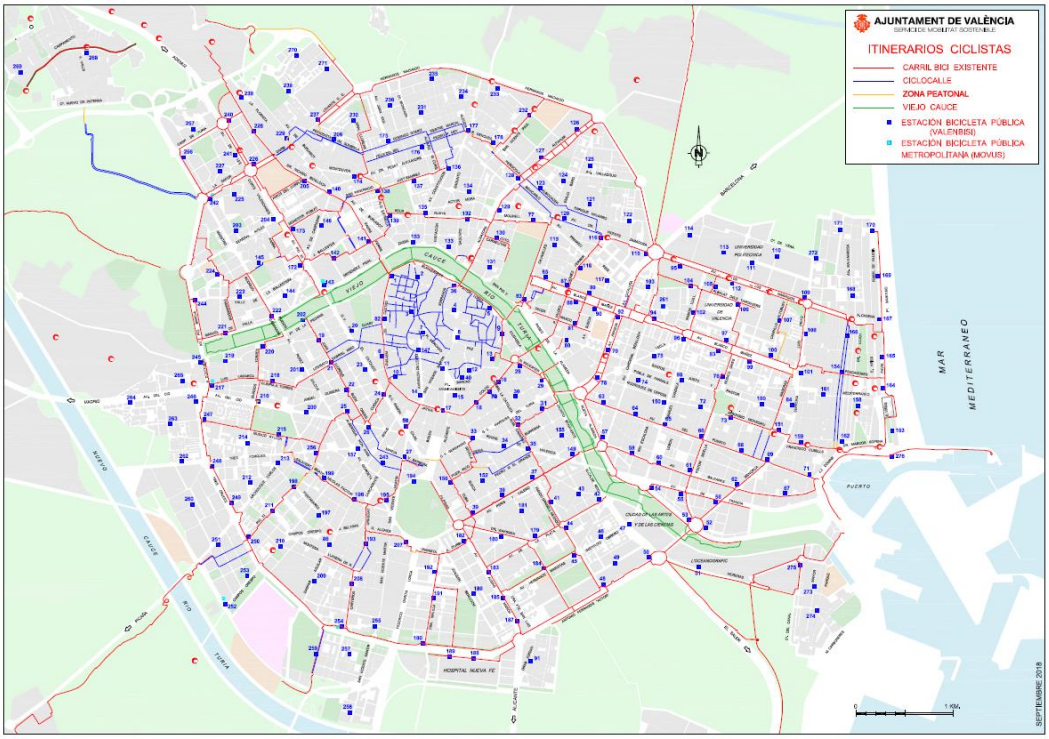


Figure 17. Bicycle lanes in Valencia and Valenbisi stations.
Source: www.valencia.es.

The stations and docks are homogeneously distributed at the city, so the service supply is accessible to the great majority of inhabitants at the urban area.

[6] PMoME (2018), Section 2.8.4: *Public renting bicycle system,* page 80.

VALENBISI			
	Stations	**Docks**	**Docks per 1.000 inhabitants**
Valencia	277	5502	6,95
1. Ciutat Vella	22	465	17,34
2. l'Eixample	15	291	6,83
3. Extramurs	17	369	7,61
4. Campanar	22	430	11,38
5. la Saïdia	13	244	5,20
6. el Pla del Real	16	404	13,31
7. l'Olivereta	16	288	5,96
8. Patraix	16	258	4,48
9. Jesús	10	185	3,54
10. Quatre Carreres	26	533	7,23
11. Poblats Marítims	26	462	8,16
12. Camins al Grau	21	428	6,55
13. Algirós	21	535	14,44
14. Benimaclet	6	96	3,31
15. Rascanya	13	235	4,45
16. Benicalap	13	230	5,04
17. Pobles del Nord	1	0	0,00
18. Pobles de l'Oest	1	20	1,43
19. Pobles del Sud	2	29	1,43

Table 3. Valenbisi: distribution of stations and docks in Valencia.
Source: 2017 City Council Statistics Report.

3.6. Taxi service

In 1986 the Valencian Taxi Joint Service Area was created. The municipalities which integrate this area are the following: Alaquás, Albal, Albalat dels Sorells, Alboraia, Albuixech, Alcàsser, Aldaia, Alfafar, Alfara del Patriarca, Almàssera, Almussafes, Benifaió, Benetússer, Beniparrell, Bonrepós i Mirambell, Burjassot, Catarroja, Foios, Godella, Lugar Nuevo de la Corona, Manises, Massalfassar, Massamagrell, Massanassa, Meliana, Mislata, Moncada, Museros, Paiporta, Paterna, Picanya, La Pobla de Farnals, Picassent, Quart de Poblet, Rafelbunyol, Rocafort, Sedaví, Silla, Sollana, Tavernes Blanques, Torrent, Valencia, Vinalesa and Xirivella.

Figure 18. Taxi in Valencia.
Source: https://goo.gl/U3WjdD.

The 2017 Statistics Report states that the number of taxi licenses has remained stable since 2007 (Table 4):

TAXI LICENSES IN VALENCIA

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2.816	2.816	2.816	2.822	2.835	2.835	2.911	2.830	2.826	2.810	2.745

Table 4. Number of taxi licenses since 2007 to 2016.
Source: 2017 City Council Statistics Report.

According to the PMoME, out of the total number of licenses, about 30% are assigned to the 122 official taxi stops located in the city. The average number of stops per 10.000 habitants is 1,5. Figure 19 shows the density of taxi stops at the different neighbourhoods of the city.

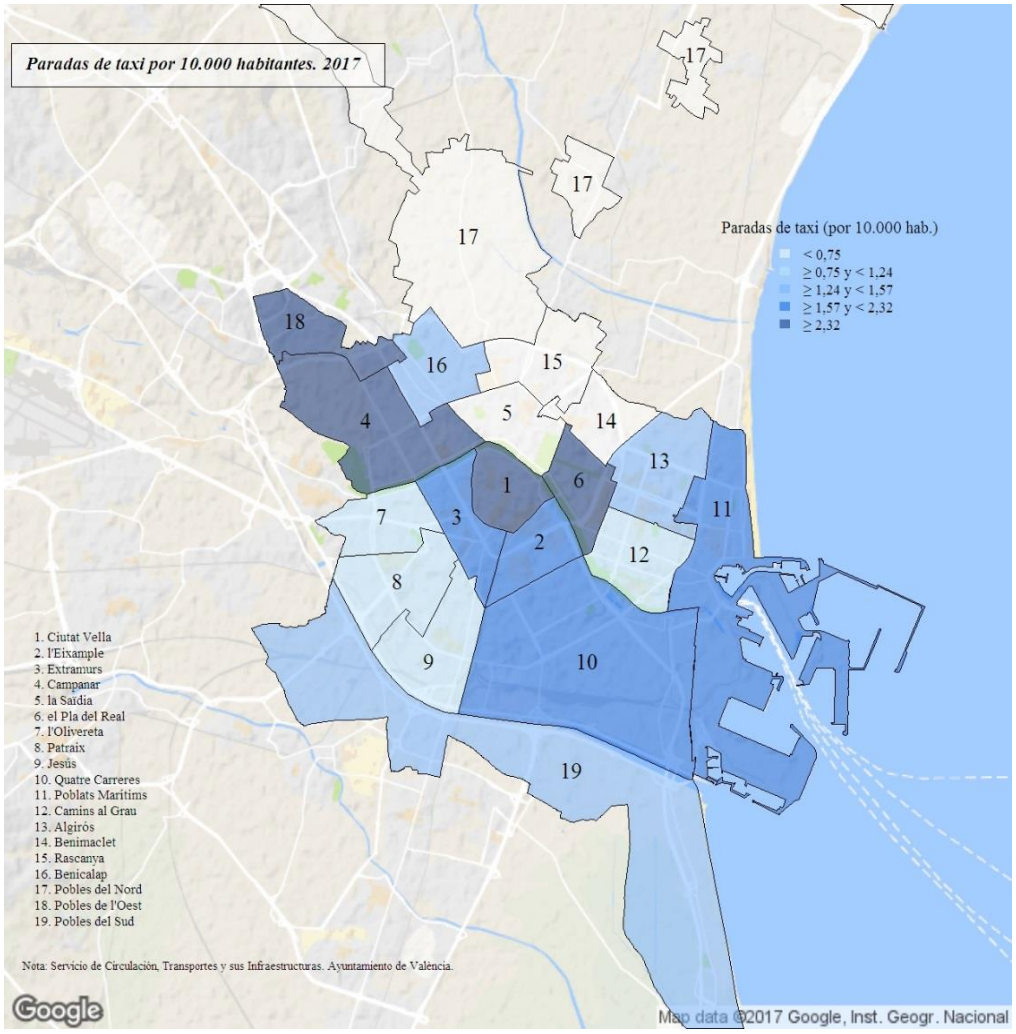
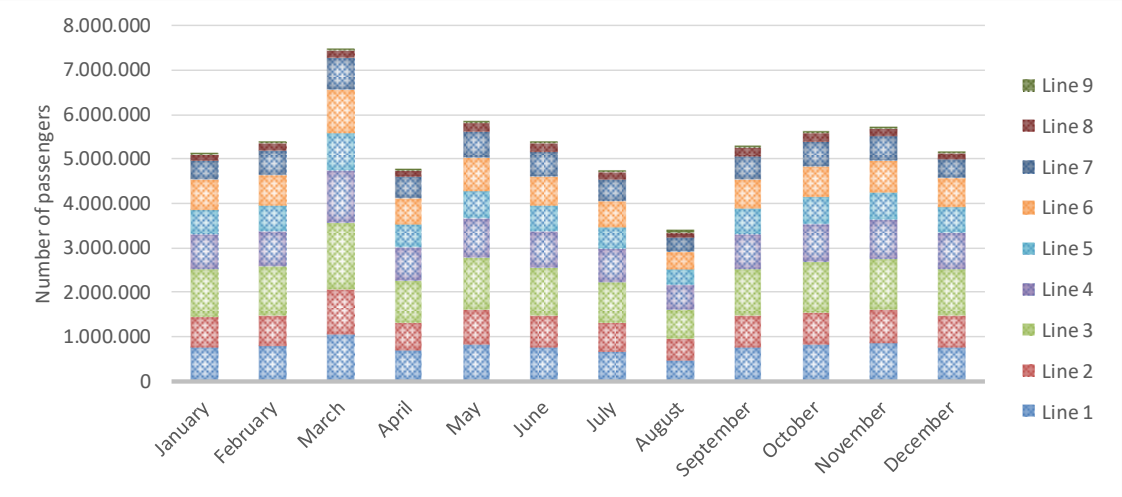


Figure 19. Taxi stops per 10.000 inhabitants.
Source: 2017 City Council Statistics Report.

4. Description of the public transport demand in Valencia

4.1. Subway "Metrovalencia" demand

Metrovalencia had a demand of 63.843.231 passengers in 2017. The monthly distribution of passengers for each of the lines is shown in Graph 2. The distribution of the demand is similar for all the lines (with some exceptions), but the most frequently used is line 3 which connects the city with the airport in Manises. Line 4 also absorbs a good amount of the demand because it links Valencia with the university campus located in Burjassot. March is the month with the highest number of passengers due to Fallas, a local festivity declared in 2016 as Intangible Cultural Heritage of Humanity by the UNESCO, that attracts a large number of foreign visitors.

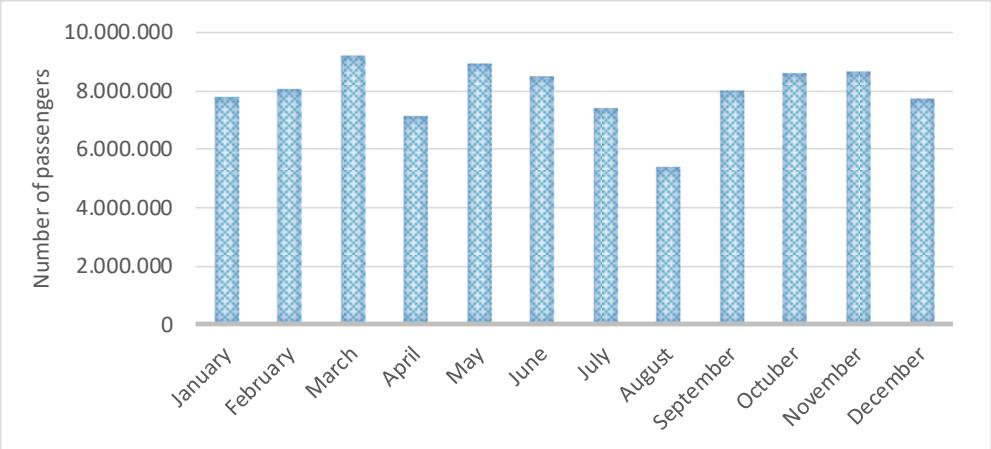


Graph 2. Passengers per month and line in 2017.
Source: 2017 City Council Statistics Report.

4.2. Urban bus "EMT Valencia" demand

According to the 2017 Statistics Report published by the City Council of Valencia, EMT Valencia transported a total of 95.494.841 passengers in 2017. The distribution of the demand per month is shown in Graph 3.

It can be appreciated that months with long holidays suffer a decrease in the number of users. This is the case of April (Easter) and July and August (summer). As it happened with Metrovalencia, the month with the highest number of passengers is March, when the population of Valencia strongly grows due to Fallas.



Graph 3. Passengers per month in 2017.
Source: 2017 City Council Statistics Report.

There are four lines which circle the city: 79, 80, 89 and 90. Lines 79 and 80 have a smaller radius and lines 89 and 90 have a bigger one, connecting the outermost neighbourhoods of Valencia. As it can be observed in Appendix 2, the lines with a higher demand are lines 89 and 90. This is an evidence of the need of public transport routes which connect the periphery of the city without passing though the centre. This same tendency is observed at the Metropolitan Region of Valencia between municipalities outside the capital. It is also important to remark that the demand of the EMT Valencia night lines has increased in the last years (the city has a significant night life).

4.3. Suburban railway "Cercanías" demand

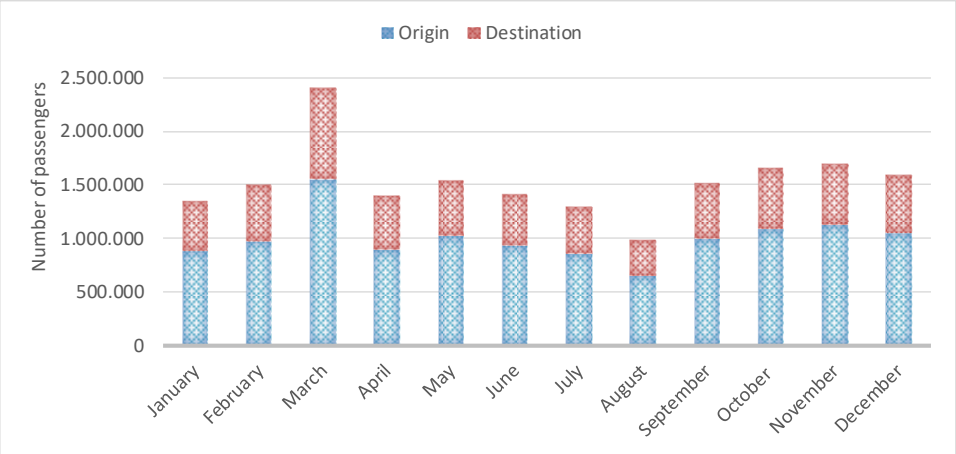
The next table contains the number of *Cercanías* passengers whose origin or destination was the city of Valencia for each of the suburban railway lines.

NUMBER OF *CERCANÍAS* PASSENGERS

Line	Total	Origin	Destination
C1	3.803.800	1.924.100	1.879.700
C2	4.267.000	2.188.400	2.078.600
C3	716.400	490.400	270.100
C4	1.500	800	700
C5	1.500	800	700
C6	36.061	19.522	16.539

Table 5. Number of passengers with Valencia as an origin or destination.
Source: 2017 City Council Statistics Report.

In 2017, 12.011.500 passengers departing from or arriving at Valencia were carried. Graph 4 shows the distribution of these passengers per month. Again, March is the month with the highest demand, as people from municipalities near the city go to the capital for the aforementioned reason.



Graph 4. Number of passengers per month whose origin or destination is the city Valencia. Source: 2017 City Council Statistics Report.

4.4. Suburban bus "Metrobús" demand

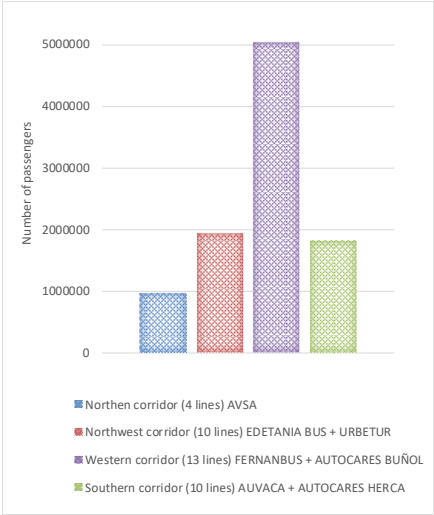
As explained in section 3.4, the suburban bus network is operated on a concession basis. Until this moment, service has been provided by seven companies[7]:

- AVSA provided with five lines covering the northern corridor and carried 964.241 passengers in 2017.
- EDETANIA BUS offered eight lines covering the northwest corridor and gave service to 1.922.841 passengers in 2017.
- URBETUR provided two lines who covered two northwest routes and transported 13.488 passengers in 2017.
- AUTOBUSES BUÑOL operated seven lines in the western corridor and carried 260.357 passengers in 2017.
- FERNANBUS covered as well the western corridor with seven lines and gave service to 4.773.155 passengers in 2017.
- AUVACA S.A. offered five lines covering a part of the southern corridor and transported 1.595.503 passengers in 2017.

[7] City Council Statistical Office (Oficina de Estadística del Ayuntamiento de Valencia), website: https://www.valencia.es/ayuntamiento/anuario.nsf/fCategoriaVista?readForm&nivel=6_2&Vista=vListadoAnuario&Categoria=Anuario 2017&lang=1&expand=4&subexpandido=5&bdorigen=ayuntamiento/estadistica.nsf

- AUTOCARES HERCA S.L. covered other southern routes with four lines and carried 218.073 passengers in 2017.

Metrobús carried 9.646.658 passengers in 2017. Graph 5 illustrates the number of users grouped in corridors (as were defined in section 3.4). It can be seen that the western corridor, operated by two of the companies mentioned above, concentrate about 60% of the demand of the service, despite of the fact that its number of lines is very similar to the ones in the northwest and southern corridors.



Graph 5. Number of Metrobús passengers per corridor in 2017.
Source: 2017 City Council Statistics Report.

4.5. Public bicycle "Valenbisi" demand

This public bicycle system works mainly through an annual subscription. However, it is also possible to obtain a pass for some days (mostly used by tourists). Table 6 shows the number of annual and short term subscriptions per month in 2017.

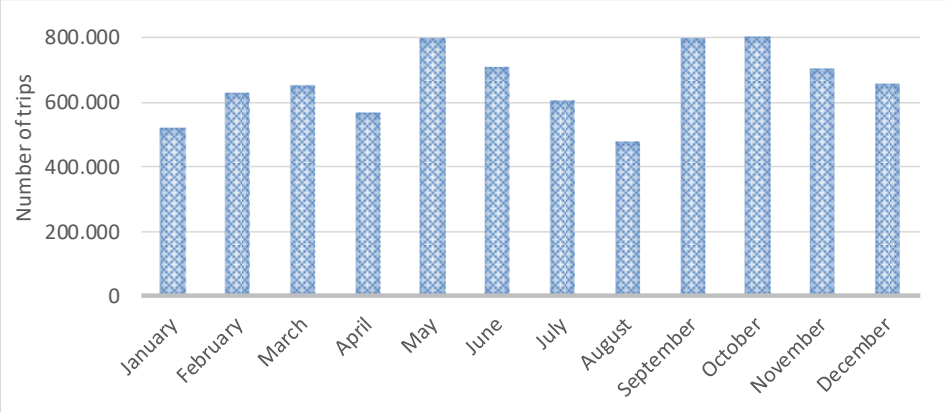
VALENBISI SUBSCRIPTIONS

	Annual subscriptions	Short term subscriptions	Total
January	44.440	486	44.926
February	44.267	671	44.938
March	45.267	1.329	46.596
April	45.329	1.921	47.250
May	45.803	2.003	47.806
June	45.894	2.327	48.221

July	45.760	3.344	49.104
August	45.784	3.933	49.717
September	46.140	3.014	49.154
October	46.190	2.592	48.782
November	46.207	1.668	47.875
December	46.044	1.012	47.056

Table 6. Valenbisi subscriptions per month in 2017.
Source: 2017 City Council Statistics Report.

The total number of trips made by Valenbisi in 2017 was 8.928.853 and the monthly distribution of Valenbisi demand is the next one:

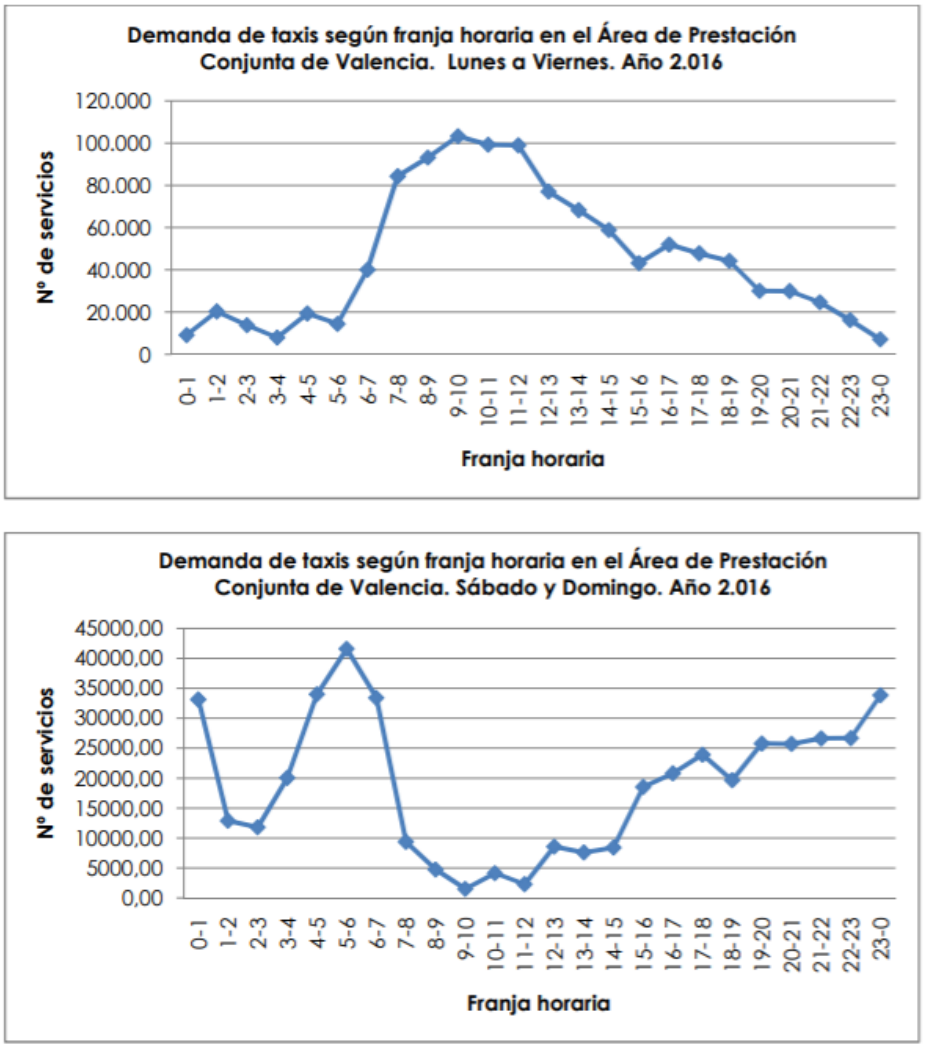


Graph 6. Trips per month made by Valenbisi.
Source: 2017 City Council Statistics Report.

4.6. Taxi service demand

The main motives for using a Taxi are leisure activities, going to the airport or train station, work displacements, medical transfers, etc. The demand at each hour of the day is described in the following graphics. The first one illustrates the annual demand of the taxi service during weekdays and the second one, during weekends[8].

[8] Information obtained from the *Study for the Situation of the Taxi in the Valencian Taxi Joint Service Area* (2007), published by the Valencian Ministry of Housing, Public Works and Territorial Planning. www.habitatge.gva.es.



Graph 7. Number of annual trips in 2016 made by the taxi during weekdays (above) and during weekends (below) in Valencia. Source: Study for the Situation of the Taxi in the Valencian Taxi Joint Service Area (2007).

As it will be seen later in Graph 8, this mode of transport only represents a 0,4% of the modal split at the Metropolitan Region of Valencia, so its use is minor and does not represent a competence factor against other modes.

5. Analysis of mobility in Valencia: current situation

After having revised in sections 3 and 4 the basic data about public transport network and demand in Valencia, now we are going to join all the information in order to expose the global public transport network situation in the Metropolitan Region.

Metropolitan public transport in Valencia is distributed radially from the city of Valencia, offering a transport service through corridors which are not interconnected. Figure 20 shows the existing subway, suburban train and suburban bus existing lines, which conform the whole public transport supply serving the Metropolitan Area of Valencia. The nine subway and six suburban train lines are headed to the different cardinal directions with no crossings between them once at the suburbs of the city. Furthermore, the suburban bus network runs redundantly through many of the routes which are already covered by the subway and the suburban train. Only at the West zone some circumferential connections are established. However, when analysing these connections in more detail, it can be noticed that the supply is scarce and that it does not properly connect some population nucleuses that are a source of a great amount of trips, such as the towns of Quart de Poblet or Torrent.

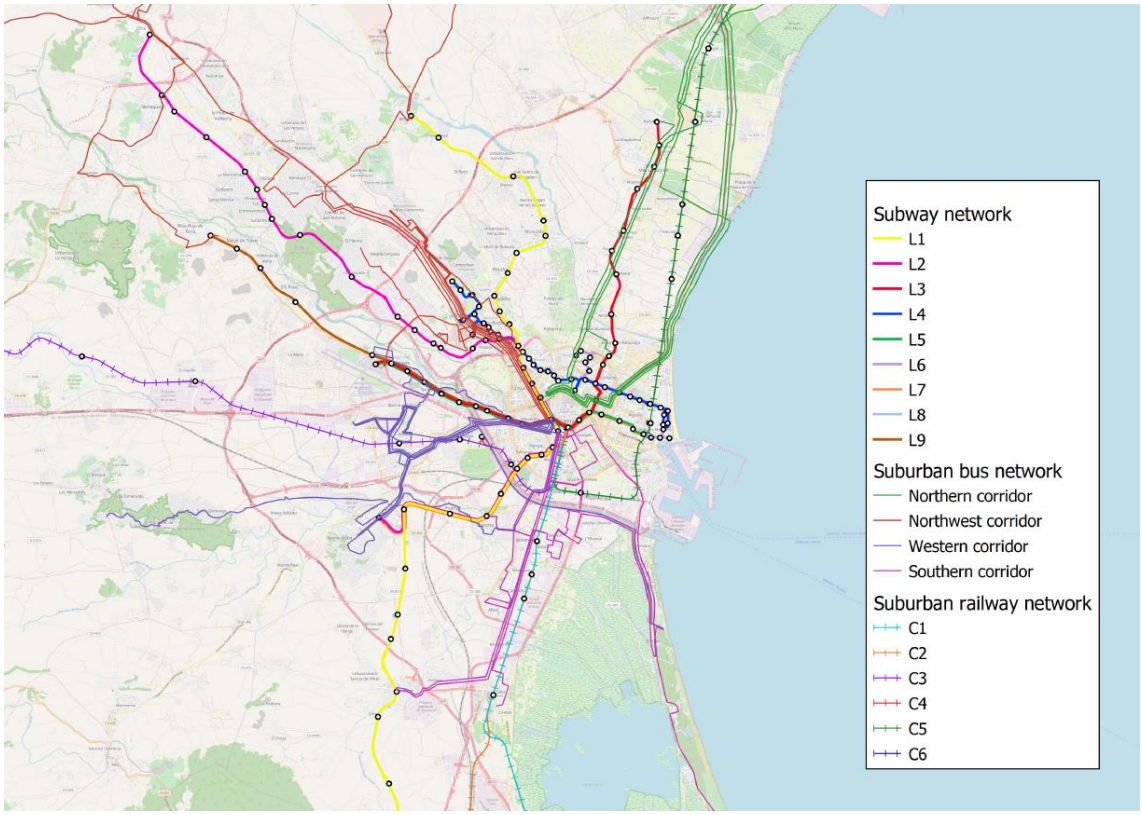
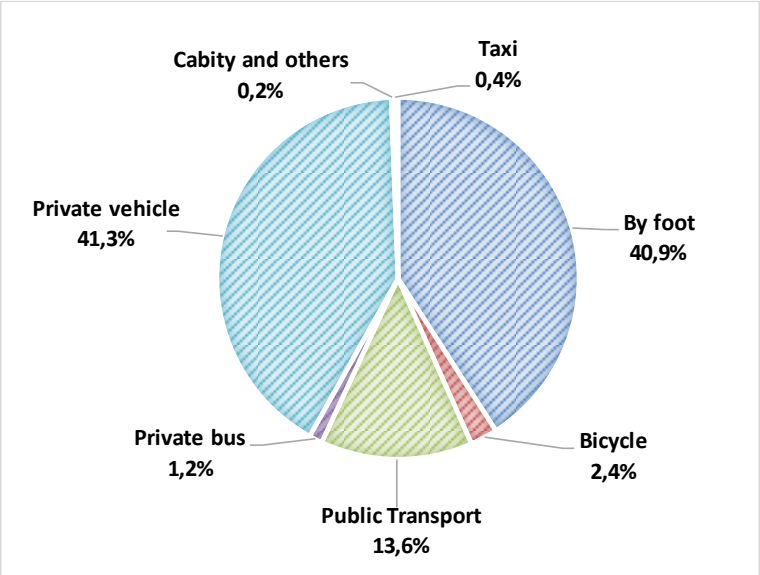


Figure 20. Public Transport supply connection the Metropolitan Area of Valencia.
Source: Own elaboration.

In the three next subsections we will analyse how the use of the different modes of transport is distributed and we will describe the main characteristics of trips. We will go on identifying and focusing on the most relevant displacements for our study, according to the information available at the demographic data matrix and trip data matrix that were elaborated for the development of the PMoME.

5.1. Modal split and mobility flows at the Metropolitan Area of Valencia

The majority of trips in Valencia and its Metropolitan Region are made by private vehicle (41,3%), and by foot (40,9%), followed by public transport (13,6%). Only 2,4% are made by bicycle. There are other minority modes such as private bus, taxi or car services such as Cabify (Graph 8).



Graph 8. Modal split in Valencia and its Metropolitan Area.
Source: PMoME.

As it can be seen in Figure 21, there are some important mobility flows between nucleuses at the Metropolitan Region of Valencia which are not covered, in most of the cases, by any public transport network (see in the figure the thickest red discontinuous lines representing mobility flows between 30.000 and 60.000 trips per day). This manifests an important shortage of service at the outskirts of the city that leads to a massive use of the private vehicle (with the associated problems: traffic congestion, harmful emissions, pollution, etc.).

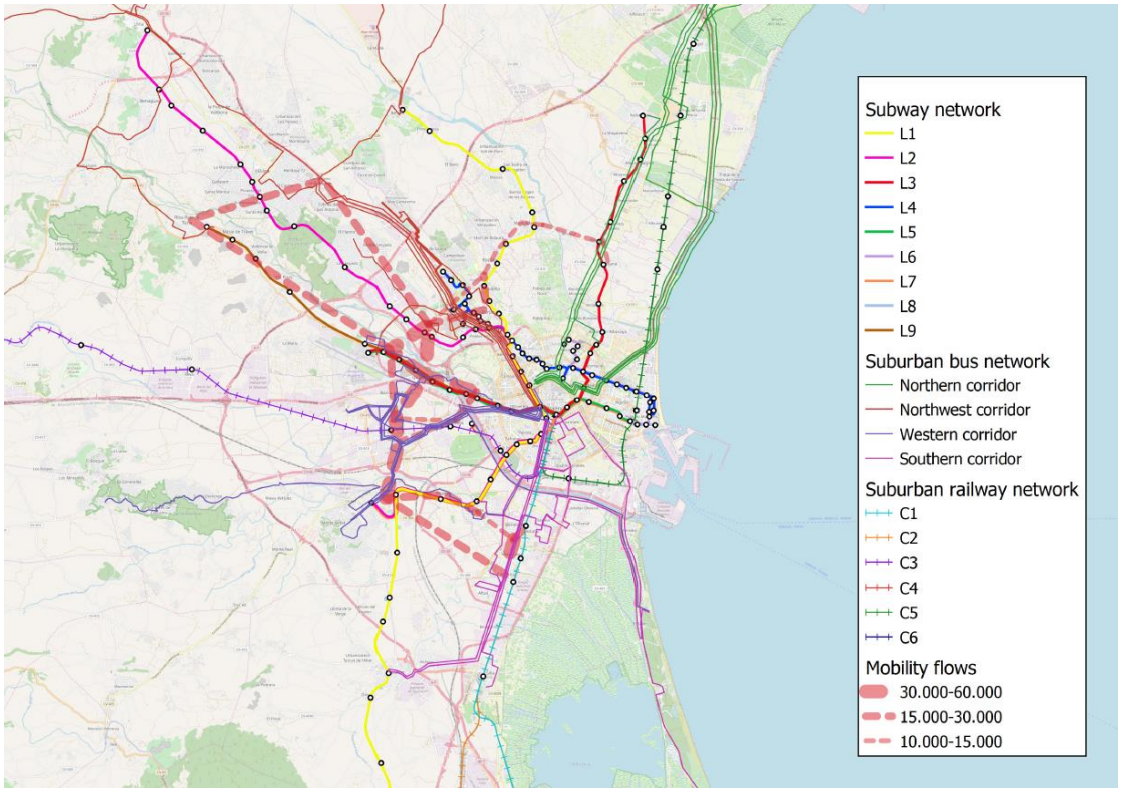
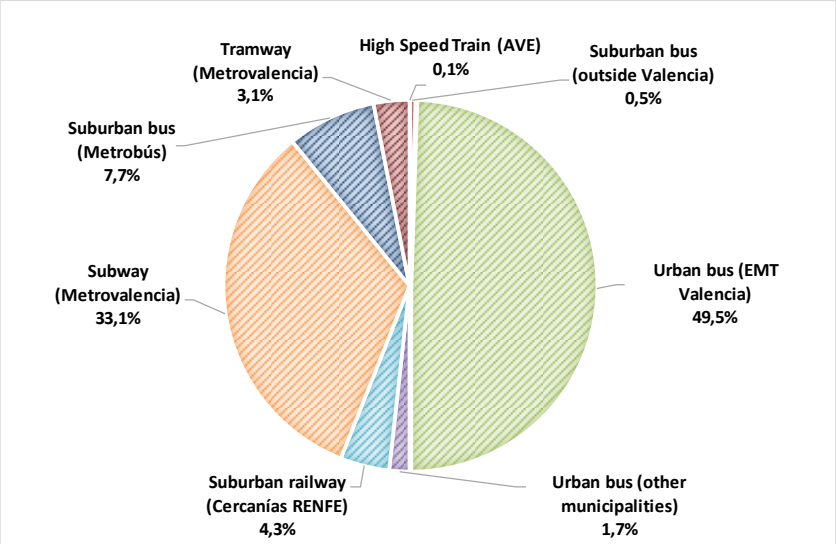


Figure 21. Main mobility flows at the Metropolitan Area of Valencia and public transport supply. Source: Own elaboration.

In accordance with the lack of supply, it is obvious that the need of an improved and extended public transport network arises. Taking into account the big economical and technical effort that involves at this time the construction of new subway or tramway lines (which would confer municipalities with the optimal service in terms of speed and comfort), the best option for solving the problem consists in the implementation of some extra suburban bus lines (Metrobús) connecting nucleuses between which there are important mobility flows.

As it has been shown in Graph 8, the part of modal split corresponding to public transport is 13,6%. The distribution of this share between each public transport mode is represented in Graph 9.



Graph 9. Modal split of public transport.
Source: Own Elaboration.

Only 7,7% of the 13,6% public transport share corresponds to suburban bus, so the modal split of Metrobús in relation to all modes of transport is 1,05%. The low percentage of use of the suburban bus suggests that this public transport mode is not attractive enough for inhabitants at peripheral areas. For this reason, before implementing any new Metrobús line, it is a priority to analyse in detail the variables that determine the choice of the transport mode for a specific trip. To do so, we will proceed to study the mobility that comply with the following requisites:

- The person doing the trip should have the option whether to use the private vehicle or Metrobús, so he should have an available car or motorcycle.
- The trip should be made within an origin and a destination only linked by Metrobús as public transport service.

The data, obtained from the aforementioned phone travel survey, can be consulted at the website of the PMoME[9]. As it has been said in previous sections, the whole data is subdivided into two matrices: the demographic data matrix and the trips data matrix.

5.2. Identification of relevant trips for the study

The first step towards this analysis consists in identifying at the demographic data matrix the group of people who have access to a private vehicle. For making this selection, column EV_09

[9] Website of the PMoME: https://www.pmomevalencia.com.

of this matrix, which indicates the availability of a private vehicle, has been used. The possible answers (to the phone travel survey) at this column were:

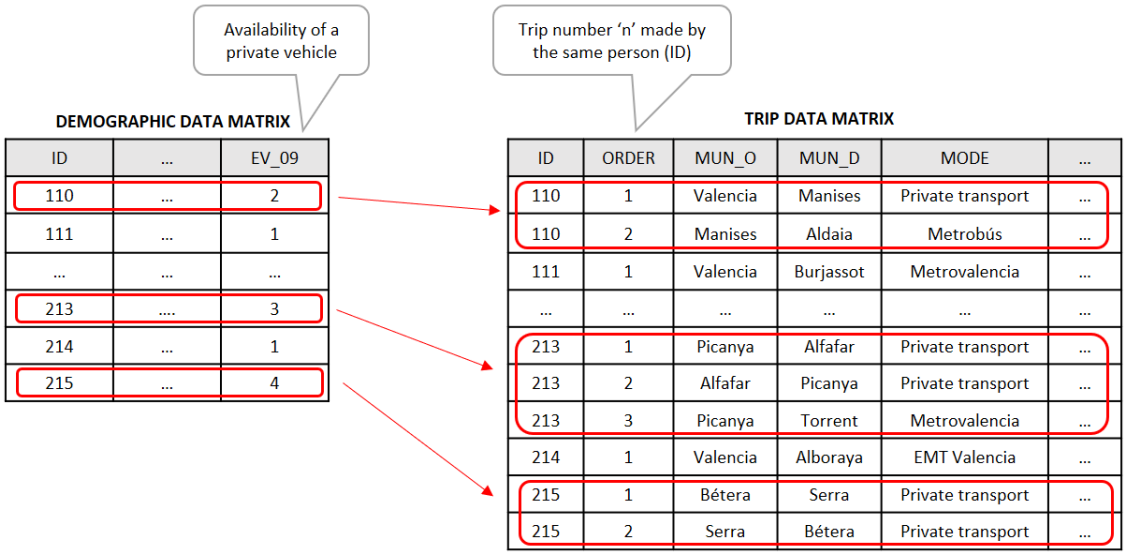
1	-	No
2	-	Yes, and I use it
3	-	Yes, and I use it sometimes
4	-	Yes, but I do not use it
5	-	Yes, but I am not the one driving
9	-	Does not know/does not answer

Figure 22. Possible answers for indicating the availability of a private vehicle at the survey.
Source: PMoME.

Respondents who have answered 2 ("Yes, and I use it"), 3 ("Yes, and I use it sometimes"), 4 ("Yes, but I do not use it") or 5 ("Yes, but I am not the one driving") have been identified, as they have answered affirmatively to the fact of having an available private vehicle.

Regarding the trip data matrix, each row corresponds to a specific trip (no matter the mode of transport that has been chosen) and columns describe different aspects of the respective displacement (such as the identification of the person responding, the origin, the destination, the mode of transport or the motive of the trip, among others). One person can do various displacements within a day, so various rows can correspond to different trips made by the same respondent.

Crossing the data between the demographic and the trip data matrix, we have isolated in a submatrix, using Excel, those displacements corresponding to people with access to a private vehicle.



ID	...	EV_09
110	...	2
111	...	1
...	...	...
213	....	3
214	...	1
215	...	4

ID	ORDER	MUN_O	MUN_D	MODE	...
110	1	Valencia	Manises	Private transport	...
110	2	Manises	Aldaia	Metrobús	...
111	1	Valencia	Burjassot	Metrovalencia	...
...	...	...	...	...	...
213	1	Picanya	Alfafar	Private transport	...
213	2	Alfafar	Picanya	Private transport	...
213	3	Picanya	Torrent	Metrovalencia	...
214	1	Valencia	Alboraya	EMT Valencia	...
215	1	Bétera	Serra	Private transport	...
215	2	Serra	Bétera	Private transport	...

Figure 23. Example of how the data has been selected in Excel.
Source: Own elaboration.

However, only those trips who are made within a route covered by any suburban bus line are significant for us. The Excel native function CONCATENATE and others have been employed to determine, for each suburban bus line, the set of possible combinations of origin and destination depending on the existing bus stops. The same function has been used in a column called "Origin_Destination" at the submatrix to enter in the same cell both the origin and destination (see Figure 25 below). For example: on the one hand, for a passenger with Bétera as origin and Serra as destination, the cell at the column "Origin_Destination" would indicate "Bétera_Serra"; on the other hand, for line 6 of the northwest corridor of Metrobús, whose stops are Bétera, Náquera and Serra, the possible path combinations are the following:

"Bétera_Bétera"	"Náquera_Bétera"	"Serra_Bétera"
"Bétera_Náquera"	"Náquera_Náquera"	"Serra_Náquera"
"Bétera_Serra"	"Náquera_Serra"	"Serra_Serra"

Figure 24. Example of set of possible origins and destinations.
Source: Own elaboration.

A new column called "Connected by Metrobús?" has been created in the Excel submatrix. In case the Origin_Destination matches one of the routes covered by Metrobús, this cell would indicate "Yes".

Two more conditions should be accomplished for a respondent of the survey to be considered a potential Metrobús passenger for doing a specific trip. First of all, the origin and the destination should not be the same since, in that case, it will not be necessary to use any mode of transport in most cases. Secondly, there should not be another public transport option, just only the suburban bus should be available. Therefore, the same method used for Metrobús has been used to obtain the set of possible origin and destinations covered by Metrovalencia and Cercanías Renfe (which are the alternative public transport systems that cover the Metropolitan Region of Valencia).

Finally, a last column called "Potential Metrobús user?" has been included in the submatrix. In case all the above requirements are met, it will indicate "Yes".

SUBMATRIX

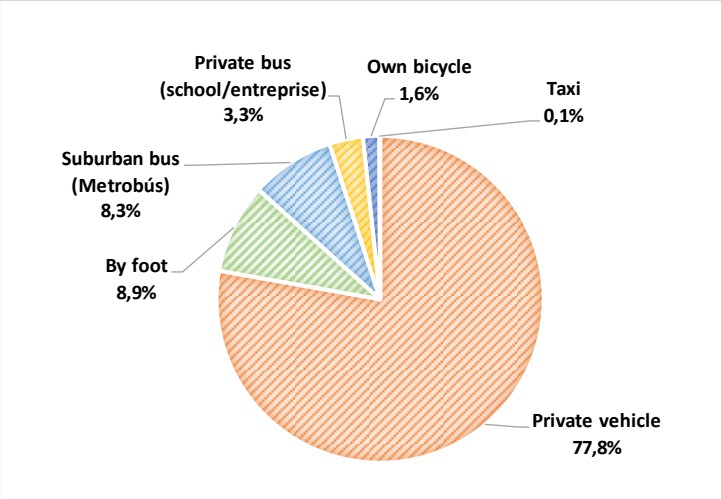
ID	ORDER	MUN_O	MUN_D	Origin_Destination	Mode	Connected by Metrobús?	Connected by Metrovalencia?	Connected by Cercanías?	Potential Metrobús user?	...
110	1	Valencia	Manises	Valencia_Manises	Private transport	Yes	Yes	No	No	...
110	2	Manises	Aldaia	Manises_Aldaia	Metrobús	Yes	No	No	Yes	...
...	...	...	...	...	...	...	...	...	...	...
213	1	Picanya	Alfafar	Picanya_Alfafar	Private transport	No	No	No	No	...
213	2	Alfafar	Picanya	Alfafar_Picanya	Private transport	No	No	No	No	...
213	3	Picanya	Torrent	Picanya_Torrent	Metrovalencia	No	No	No	No	...
215	1	Bétera	Serra	Bétera_Serra	Private transport	Yes	No	No	Yes	...
215	2	Serra	Bétera	Serra_Bétera	Private transport	Yes	No	No	Yes	...

Figure 25. Example of how the data has been treated in Excel.
Source: Own elaboration.

As it had been intended in this subsection 5.2, we have finally identified the trips that fit the conditions established at subsection 5.1. Now, we are going to analyse the characteristics of these trips.

5.3. Characteristics of trips made by potential suburban bus users

Having identified the potential suburban bus users and their respective displacements, it is convenient to investigate the modal split of this group of passengers in order to describe the characteristics of trips. Graph 10 represents the distribution of the use of the different public and private transport modes.



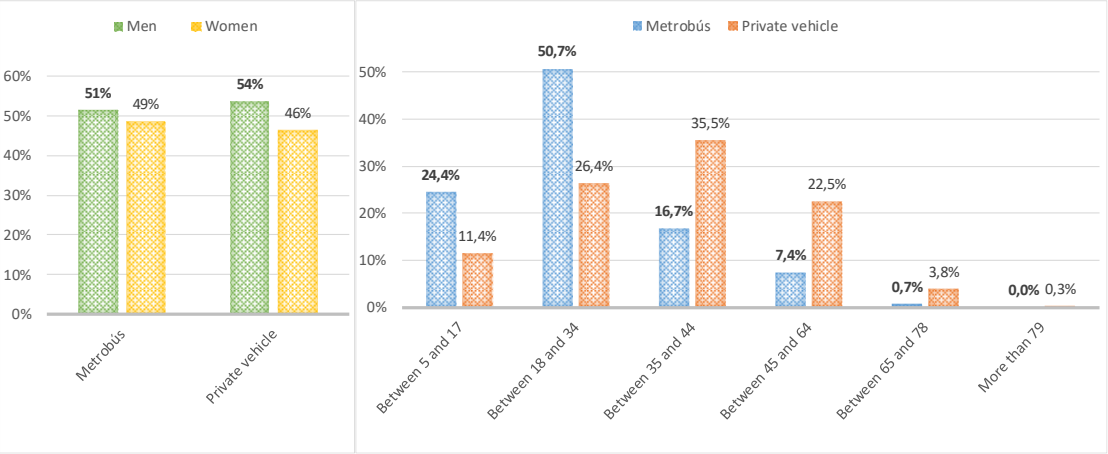
Graph 10. Modal split of potential suburban bus users.
Source: Own elaboration.

It is observed that Metrobús is used only by 8,3% of the selected trips. However, the dominating mode is the private vehicle (77,8%), followed by walking (8,9%).

Once again, the hypothesis that the suburban bus is not an attractive option is reaffirmed. However, Metrobús is the unique viable transport method against the private vehicle, as users of the private bus (school/entreprises), cyclists and walkers are already using a specific transport mode as a result of a conscious decision. In addition, these latest transport systems do not actually compete against the suburban bus. In consequence, our work will be continue analysing the displacements that are made only by the suburban bus (Metrobús) and the private vehicle, considering aspects related to personal characteristics (such as gender, age, and reasons for moving), and characteristics of the trips (duration of the displacement, cost).

5.3.1. Gender and age

The distribution of gender and age of passengers are indicated in Graph 11. Normally, women tend to use more the public transport than men; however, as the trip selection corresponds to people having an available private vehicle, the obtained distribution between gender is balanced between men and woman. However, the age distribution between modes is not. While the suburban bus is mostly used by passengers between 18 and 34, the private vehicle is mainly used by people within 35 and 44 years old.



Graph 11. Gender and age distribution of passengers.
Source: Own elaboration.

5.3.2. Trip purpose

Regarding the different motives of trips (summarised in Table 7) and in accordance with the age distribution results, the most predominant motive for using the suburban bus are studies (trips to educational and university centres). In the same way, the main motive for using the private vehicle is the need for arriving fast and straight to the working place.

MOTIVES BEHIND TRIPS

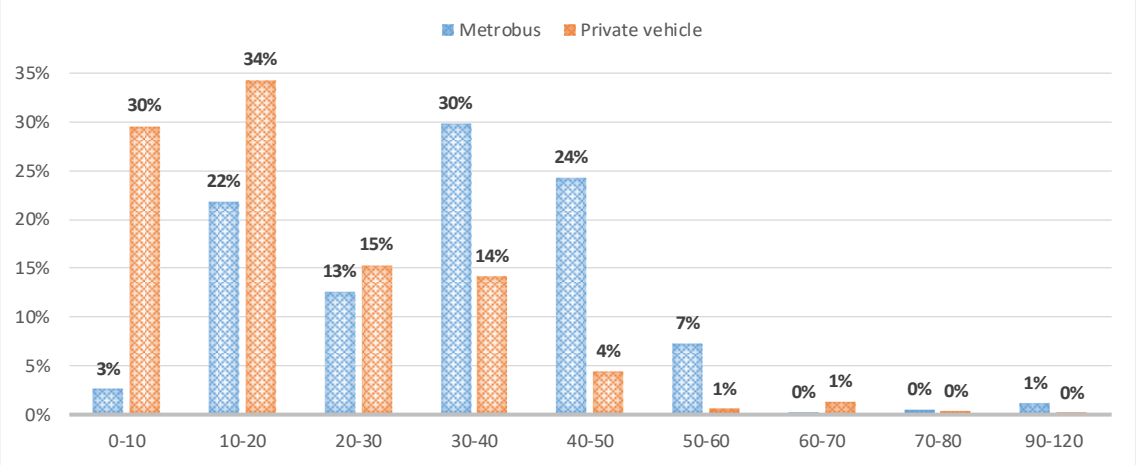
	Metrobús	**Private vehicle**
Studies	**71,6%**	14,9%
Everyday purchases	11,7%	6,2%
Work	10,9%	**38,6%**
Going to the doctor	2,9%	3,3%
Visiting familiy and friends	1,3%	2,9%
Personal affairs	0,8%	7,8%
Accompany people	0,5%	9,0%

Leisure activities	0,4%	5,7%
Shopping	-	2,9%
Sport, gym, etc.	-	4,7%
Job-related trips	-	1,7%
Hotel/family house	-	0,6%
Other reasons	-	1,7%

Table 7. Motive behind trips made with suburban bus and private vehicles.
Source: Own elaboration.

5.3.3. Trip duration

The travel time distribution is shown in Graph 12. The average travel time using the suburban bus is 32 minutes, and average travel time using the private vehicle is 19 minutes (a 40% lower).



Graph 12. Time travel distribution.
Source: Own elaboration.

5.3.4. Cost of the trip

For each displacement, we have calculated both the cost in case of using the private vehicle and the suburban bus:

1) The cost of the trip by private vehicle is calculated as a function of the price of fuel, the average fuel consumption of a car and the average speed of the vehicle:

- The cost of fuel has been obtained through the Spanish Energy, Tourism and Digital Agenda Ministry[10] on the date of the 10th of January. The average cost of gasoline in Spain is 1,189 €/litre and the average cost of diesel is 1,149 €/litre. As the rolling stock is equilibrated between gasoline and diesel, the cost per litre has been defined as the mean of the costs of each type of carburant, that is, 1,169 €/litre.
- The average fuel consumption of a car has been estimated in 6 litres of carburant per 100 kilometres, according to information provided by car constructors.
- The average speed has been defined in 65 kilometres per hour for the type of displacements that we are considering.

With these three data, it has been possible to evaluate the cost of the private vehicle using the following expression:

$$Cost\ [€] = duration\ [min] \cdot cost\ fuel\ \left[\frac{€}{l}\right] \cdot consumption\ \left[\frac{l}{km}\right] \cdot average\ speed\ \left[\frac{km}{min}\right]$$
$$= duration\ [min] \cdot 1{,}169\ \left[\frac{€}{l}\right] \cdot \frac{6}{100}\ \left[\frac{l}{km}\right] \cdot \frac{65}{60} \cdot \left[\frac{km}{min}\right] \quad \text{(Eq. 2)}$$

2) On the other hand, we have calculated cost of the trip using Metrobús according to the current fare prices

As a result of the previous analysis, we conclude that the average cost of trips using a private vehicle is 1,38 euro, and 1,64€ using Metrobús.

5.3.5. Behavioural considerations

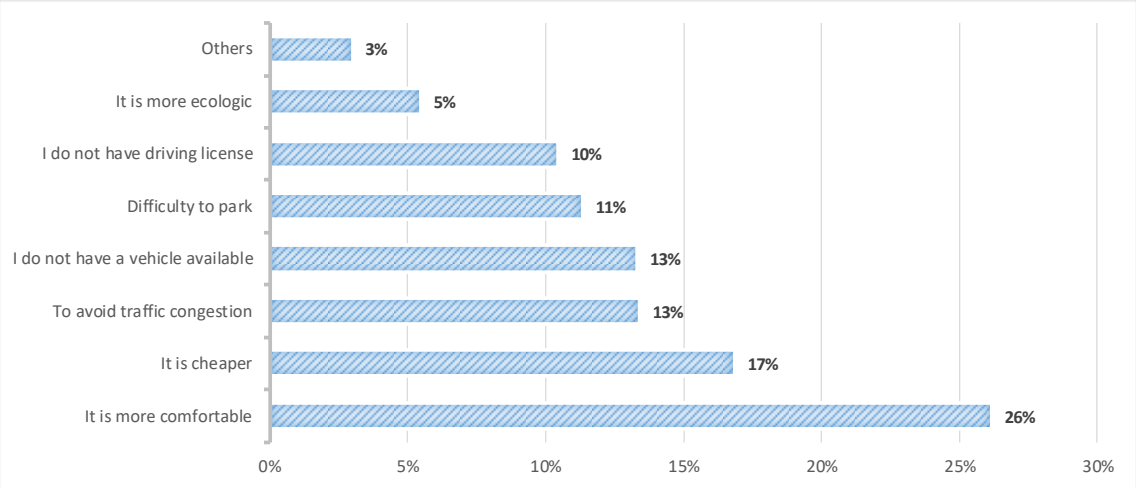
As it is of our interest to reduce the use of the private vehicle in favour of the public transport, it is important to know the reasons that lead people to refuse using public transportation. Table 8 shows that the main reason consists on the lack of a public transport service or on the fact that it is not appropriate, with 49,28% of the responses. Other reasons are referred to the suburban bus schedule, and sum up a total of a 19,50% of the responses. 9,19% of respondents state that public transport is not comfortable enough.

[10] *Price of fuel in Spain, website: http://datos.gob.es/es/catalogo/e04990201-precio-de-carburantes-en-las-gasolineras-espanolas*

REASONS FOR NOT USING THE PUBLIC TRANSPORT	
There is no public transport service or it is inappropriate	49,28%
Inappropriate schedule	10,48%
It is not comfortable	9,19%
Low frequency	9,11%
Too slow	7,17%
Other reasons	6,10%
Price	2,48%
I do not know about the public transport service	2,23%
Carrying out other consecutive activities	1,58%
Lack of punctuality	1,57%
I am close to my destination	0,76%
I have to pay more than one ticket	0,04%

Table 8. Reasons for not using public transportation.
Source: Own elaboration.

Metrobús users affirm that they take the suburban bus because it is more comfortable than other modes (26%), it is cheaper (17%) and avoid congestions (13%). It should be taken into account that the trips considered in our analysis fit the conditions described in section 5.1, so the passengers should have a private vehicle available[11] and for this reason the majority of them will have a driving license; only 10% state that they do not use another method because they do not have the driving permission.



Graph 13. Reasons for using suburban bus (Metrobús).
Source: Own elaboration.

[11] Paradoxically there are inconsistent answers in the PMoME survey (13% of respondents state that they do not have a vehicle available), maybe due to misunderstandings when taking the survey.

6. The discrete choice model

Now, it is time to go on with the specification of a choice model which aims to obtain the probability of choosing a certain mode of transport. We will begin with a theoretical description of the discrete choice model, we will continue by detailing the variables that will be used, and we will finish by estimating the model with the adequate software.

6.1. Model specification: the Logit model

Three main questions should be answered for estimating the transport demand:

1. Which are the different options for doing a trip?
2. Which are the variables that influence the decision of doing a trip with a certain mode of transport?
3. Which is the mathematical model that represents the user's choice based on the variables that affect the decision of doing a trip?

The first question involves the identification of the available modes of transport (private vehicle, subway, bus, etc.).

The second one consists in the identification of the variables that affect in the decision of doing a trip (gender and age of the passenger, duration of the trip, cost, etc.) with a certain mode of transport. In order to carry out this task, it is necessary to collect data.

Between the 60s and the 80s, statistic models were made based on observations of the elections of passengers. From these observations, analysts tried to explain the attributes that influenced the decision of choosing a certain mode of transport. These are called *revealed preferences*. The way of obtaining information can be through direct observations or through origin-destination surveys made to passenger. No matter how the information has been obtained, the relevant idea is that the data responds to real elections of passengers. However, the application of this principle requires the collection of an enormous amount of information and does not give the answer to every question. Limitations are:

- There can exist correlation between variables.
- The variability of the value of attributes along the sample can be small.
- The impact of qualitative variables can be difficulty to evaluate.
- It is not possible to evaluate those options who do not exist inside the market.

At the late 80s, another approach was born, based on experimental research techniques which could be applied to the field of transport. Passengers were interviewed and asked about elections based on different hypothetical situations. These are called *declared preferences* and allow to gather further information such as how the variation of the value of the variables affect in the decision of choosing a certain mode of transport. However, this method also has some limitations. According to Pompilio (2006), these limitations are:

- Rationalization bias, whereby the respondent provides unrealistic answers in an attempt to rationalize his behaviour. This has been associated with a subconscious phenomenon called *cognitive dissonance*. Thus, the real choices would not be the declared ones.
- Affirmation bias, that occurs when the interviewee, whether consciously or not, declares preferences that, in his opinion, are what the interviewer wishes to hear.
- Political bias, when the interviewee intentionally responds to support political decisions (Ortúzar, 2000).
- Interaction bias between the interviewer and the interviewee.
- Non-restriction bias, whereby the respondent may give unrealistic answers if he does not consider that there could be some practical restrictions impeding certain behaviours.
- Random bias, that is, the interviewee may misunderstand questions and give non real answers.
- Non-response bias, common to any type of survey.

These bias imply the possible existence of measurement error. These limitations have been overcome by improving the statistical techniques applied in the surveys. Therefore, forecasts related to the election of mode of transport, the route or the time of travel have also been improved.

The third question, the specification of the mathematical model for representing the choice as a function of the independent variables, requires the definition of a choice model based on an appropriate hypothesis, which in this case is the following: when an option is chosen, a preference for a certain alternative is manifested. Therefore, the theoretical framework for making forecasts of transport demand is based on the Utility Theory, a concept that emerged in the field of economics and whose basic assumption is that human behaviour depends on the amount of usefulness that a decision generates. Likewise, the choice of transport seeks to maximize the utility derived from the different options available. A passenger will choose the alternative that maximizes his utility given the attributes of the different modes of transport and depending on their socio-economic characteristics.

The utility function can be expressed as follows:

$$U_{jq} = V_{jq} + \varepsilon_{jq} \qquad \text{(Eq. 3)}$$

where U_{jq} stands for the utility function, V_{jq} is the deterministic or systemic terminus and ε_{jq} represents the random component of the utility, which includes all the factors that are not known by the analyst and that may have an influence in the passenger's decision. The subindex j refers to the alternative (mode of transport) considered and the subindex q refers to the individual in the sample. In our case, as we had explained in section 5.3, it is our intention to study the distribution between two modes of transport: the private vehicle and the suburban bus "Metrobús". Therefore, we will be facing a binary model.

The systemic part of the utility, V_{jq}, is a linear function expressed as follows:

$$V_{jq} = \beta_{0j} + \sum_{k} \beta_{kj}\ x_{kjq} \qquad \text{(Eq. 4)}$$

being:

- j = mode of transport.
- q = individual who makes a certain trip.
- k = number of attributes that influence in the individual q decision of a certain j mode of transport.
- x = each one of the k attributes, that is, the k variables at our model.
- β_{0j} = constant term which is specific for each j mode of transport, and represents the influence of the non-observed characteristics.
- β_{kj} = for attribute k, parameter that is assumed constant for every individual q, but can vary within the different modes of transport j.

A passenger will choose the option which maximizes his utility, that is, the individual q will choose the j mode of transport if he perceives that this option generates a higher utility than any other i alternative mode of transport:

$$U_{jq} \geq U_{iq} \qquad \text{(Eq. 5)}$$

where subindex i and j are referred to the two possible modes of transport in this binary model. That is:

$$V_{jq} + \varepsilon_{jq} \geq V_{iq} + \varepsilon_{iq} \qquad \text{(Eq. 6)}$$

$$V_{jq} - V_{iq} \geq \varepsilon_{iq} - \varepsilon_{jq} \qquad \text{(Eq. 7)}$$

The probability that an individual q choses mode j, being i the alternative, is given by the following expression:

$$P_{jq} = P\left[\varepsilon_{iq} - \varepsilon_{jq} \leq V_{jq} - V_{iq}, \qquad \forall i \neq j\right] \qquad \text{(Eq. 8)}$$

At this point, it is not possible to give an analytical expression for the model without adopting any statistical assumptions about the random component function ε. For this reason, a series of hypothesis must me made:

- The first one is the consideration of the function to be independent and identically distributed.
- The second one refers to the shape of its probability distribution. Different forms for the probability distribution of the difference $\varepsilon_{iq} - \varepsilon_{jq}$ generates different models. Assuming that the distribution corresponds to a Gumbel function, also known as a Type I Extreme Values distribution, it can be demonstrated that the difference $\varepsilon_{iq} - \varepsilon_{jq}$ follows a Logit model.

The right term in the inequality (Eq. 8), $V_{jq} - V_{iq}$, is an accumulated distribution of the differences $\varepsilon_{iq} - \varepsilon_{jq}$, so the probability (for an individual making a certain trip, that is, certain q of choosing option j against option i in the Logit model is given by the logistic density function:

$$P(j) = \frac{e^{V_j}}{e^{V_j} + e^{V_i}} \qquad \text{(Eq. 9)}$$

The most general expression that gives the probability of option j to be chosen is the following:

$$P(j) = \frac{1}{1 + e^{-\beta^*(V_j - V_i)}} \qquad \text{(Eq. 10)}$$

where β^* is a calibration parameter (Monero Quintero, 2011), also called scale factor or precision parameter (Pompilio, 2006). As Pompilio states, when estimating a model and giving a forecast, it is assumed that the scale factor is equal to one. However, β^* can take values from zero to one, and it will be lower the higher the error in the declared preference data. In our model, we will consider β^* to be 1. Therefore:

$$P(j) = \frac{1}{1 + e^{-(V_j - V_i)}} \qquad \text{(Eq. 11)}$$

$$V_j = \beta_{0j} + \sum_k \beta_{kj}\ x_{kj} \qquad\qquad V_i = \beta_{0i} + \sum_k \beta_{ki}\ x_{ki}$$

6.2. Study variables

As we said in section 6.1, we are going to work with a number k of generic x variables that are considered relevant to the study and constitute the independent variables of the model.

The dependent variable corresponds to the mode of transport that has been chosen (the subindex j aforementioned). As it has been explained in section 5.1, the best option for solving the problem of the lack of public transport at the Metropolitan Region of Valencia consists in the implementation of new suburban bus lines connecting nucleuses between which there are important mobility flows. The selected data for the study corresponds to people who have the option of using their private vehicle and that are only served by suburban bus as public transport mode; this data has been selected with the aim of analysing in detail the reasons that determine the choice between Metrobús (subindex j) and the private vehicle (subindex i).

Independent variables are subdivided into two groups: *demographic variables* (that can be individual or household characteristics) and *trip variables* (Figure 26).

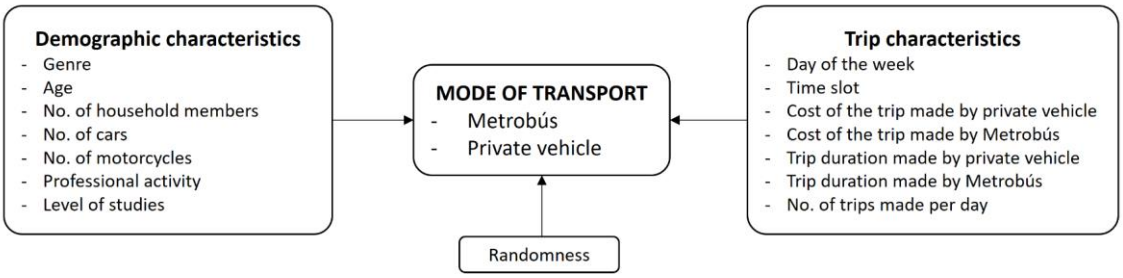


Figure 26. Variables that influence in the decision of choosing one mode of transport.
Source: Own elaboration.

The following table describes in detail the dependent variable and the various independent variables. We indicate for the categorical (discrete) variables the range of values that they can adopt as well as their respective meaning, and for the continuous variables their respective definition.

VARIABLE	RANGE/DEFINITION	TYPE
Dependent variable		
MODE	0 = Private vehicle	Categorical
	1 = Metrobús	
Independent variables		
SOCIO-DEMOGRAPHIC		
GENDER	0 = Man;	Categorical
	1 = Woman	
AGERANGE	1 = age between 5 to 17 years-old	Categorical
	2 = age between 18 to 44 years-old	
	3 = age between 45 to 64 years-old	

	4 = age between 65 to 79 years-old	
	5 = age of more than 79 years old	
NMEMBERS	Number of household members	Continuous
NCARS	Number of cars at the household	Continuous
NMOTOS	Number of motorcycles at the household[12]	Continuous
ACTIVITY	1 = Student	Categorical
	2 = Non-remunerated domestic work	
	3 = Unemployed and not looking for a job	
	4 = Unemployed and looking for a job	
	5 = Employed	
	6 = Retired	
	7 = Pensioner	
	18 = Others	
	19 = N/A	
STUDIES	1 = Without studies	Categorical
	2 = Primary studies	
	3 = Secondary studies	
	4 = University studies	
	5 = Vocational training	
	7 = Others	
	8 = Does not know	
	9 = Does not answer	
TRIP		
DAY	1 = Monday	Categorical
	2 = Tuesday	
	3 = Wednesday	
	4 = Thursday	
	5 = Friday	
SLOT	1 = Morning: between 5:00 a.m until 1:30 p.m.	Categorical
	2 = Midday: between 1:30 p.m. until 5:00 p.m.	
	3 = Afternoon: between 5:00 p.m. until 10:00 p.m.	
	4 = Night: between 10:00 p.m. until 5:00 a.m.	
DIFCOST	Difference between the cost of the trip made by private vehicle and the cost made by Metrobús	Continuous
DURCVP	Trip duration made by private vehicle	Continuous
CURCMB	Trip duration made by Metrobús	Continuous
NTRIPS	Number of trips made per day	Continuous

Table 9. Description of study variables.
Source: Own elaboration.

[12] The number of cars and motorcycles are not actually relevant because the information we use already completes the availability of a private mode of transport, no matter the number of them in the household.

6.3. Estimation of the model

The estimation of the model has been developed with *Mplus* version 7[13] using the Maximum Likelihood Estimation method. *Mplus* has no user interface and runs by programming, using a language based in a set commands[14] with several options. The commands that have been used are the next:

- *Data* command provides information about the data that will be analysed.
- *Define* command allows the creation of new variables by transforming the existing ones.
- *Variable* command gives information about the variables in the data set.
- *Analysis* command contains the technical details of the analysis.
- *Model* command describes the model which will be estimated.
- *Output* command allows to request additional output.

6.3.1. Building of the code

The code that has been written in *Mplus* for developing the model is the following:

```
Data:
     File is database.dat;
Define:
    monday = 0;       if (day == 1) then monday = 1;
    tuesday = 0;      if (day == 2) then tuesday = 1;
    wednesd = 0;      if (day == 3) then wednesd = 1;
    thursday = 0;     if (day == 4) then thursday = 1;
    friday = 0;       if (day == 5) then friday = 1;
    r5to17 = 0;       if (agerange == 1) then r5to17 = 1;
    r18to44 = 0;      if (agerange == 2) then r18to44 = 1;
    r45to64 = 0;      if (agerange == 3) then r45to64 = 1;
    r65to79 = 0;      if (agerange == 4) then r65to79 = 1;
    more79 = 0;       if (agerange == 5) then more79 = 1;
    morning = 0;      if (slot == 1) then morning = 1;
    midday = 0;       if (slot == 2) then midday = 1;
    aftern = 0;       if (slot == 3) then aftern = 1;
    night = 0;        if (slot == 4) then night = 1;
    student = 0;      if (activity == 1) then student = 1;
    domestic = 0;     if (activity == 2) then domestic = 1;
    notlook = 0;      if (activity == 3) then notlook = 1;
    looking = 0;      if (activity == 4) then looking = 1;
```

[13] *Mplus website: https://www.statmodel.com/glance.shtml*
[14] *Mplus userguide, chapter 2: Getting started with Mplus.*
https://www.statmodel.com/download/usersguide/Chapter2.pdf

```
    employed = 0     if (activity == 5) then employed = 1;
    retired = 0;     if (activity == 6) then retired = 1;
    pension = 0;     if (activity == 7) then pension = 1;
    otheract = 0;    if (activity == 18) then otheract = 1;
    actNA = 0;       if (activity == 19) then actNA = 1;
    nostud = 0;      if (studies == 1) then nostud = 1;
    primary = 0;     if (studies == 2) then primary = 1;
    second = 0;      if (studies == 3) then second = 1;
    univers = 0;     if (studies == 4) then univers = 1;
    vt = 0;          if (studies == 5) then vt = 1;
    otherstu = 0;    if (studies == 7) then otherstu = 1;
    estNA = 0;       if (studies == 8) then estNA = 1;
    estDK = 0;       if (studies == 9) then estDK = 1;
Variable:
  names = mode day woman age agerange slot costvp costmb difcost durvp durmb
  nmembers ncars nmotos activity studies ntrips;
  usevariables = mode woman difcost durvp durmb nmembers ntrips tuesday wednesd
  thursday friday r18to44 r45to64 r65to79 more79 morning aftern night student
  domestic notlook looking retired pension otheract actNA
  nostud primary second vt otherstu estDK;
  nominal = mode;
  missing are all (-999);
Analysis:
  estimator = ml;
Model:
   mode#1 ON woman difcost durvp durmb nmembers ntrips tuesday wednesd thursday
   friday r18to44 r45to64 r65to79 more79 morning aftern night  student domestic
   notlook looking retired pension otheract actNA nostud primary second vt
   otherstu estDK;
Output:
  standardized;
```

It is convenient to make some notes about the code:

1) The file *database.dat* at the *Data* command contains the values of the dependent variables and independent variables described in the previous section for the potential Metrobús trips identified in section 5.15.2. The matrix *database* can be consulted in Appendix 3.

2) At the part of the code related to the *Variable* command, the *names* item contains the headings of each column of the data matrix which correspond to each of the variables that will be evaluated. However, as it has been said, some of the variables, which happen to be the categorical variables with more than two possible answers, have been transformed at the *Define* section, as follows: the way of indicating in Mplus that a variable can adopt a range of values between, for example, 1 and 5, consists in the creation of five new columns (a sort of *dummy*

variables) that will have 0 or 1 as values depending on the value of the original variable. That occurs with many variables (see Table 9), for instance with the variable DAY that expresses the day of the week in which the trip has been done: in case DAY = 1 (Monday), the first of the five new columns that have been created (which corresponds to the variable 1, Monday) will indicate 1; the rest of the columns will be 0. In case DAY = 2 (Tuesday), the second column (which corresponds to the variable 2, Tuesday), will indicate 1 and the rest will be 0. And so on.

3) The item *usevariables* at the *Variable* section contains the set of variables that the program will estimate. Now, categorical variables with more than two possible answers have been removed and substituted by the new columns mentioned in point 1).

4) The section *Model* defines at the first place the dependent variable (*mode* of transport) followed by the variables that will explain the choice. It should be noted that results are relative in the next sense: estimations are made for a certain mode of transport (Metrobús) with respect to the other (private vehicle). The hashtag in *mode#1* indicates the mode for which results are obtained (being 1 the cardinal number indicative for Metrobús).

5) Certain variables are clearly correlated. This is the case, for example, of the DAY of the week: if we insert all the *dummy* variables (Monday, Tuesday, Wednesday, Thursday and Friday) in the model, one of them totally depends on the other four (trips not made in Tuesday, Wednesday, Thursday and Friday are obviously made on Monday); thus, the variable Monday should be removed from the code.

6) After running the program, irrelevant variables will be removed from the model by eliminating its name from the *usevariables* item at the *Variable* section and at the *Model* section.

6.3.2. Running the code

Once the model has been run at the computer, the next step consists on the identification of the relevant variables in order to purge (refine) it. We achieve this goal by using the P-value, which is a statistical tool that helps to determine the significance of the results when performing a hypothesis. Working on a basis of a small sample, the P-value test shows if the results of a study provides enough evidence *against* the null hypothesis (H_0), and therefore if it is reasonable to believe that in a larger population H_0 is false and so if we can accept the alternative hypothesis (H_1) as true[15]. In our case, the null hypothesis consists in the non-relevance of an independent variables of the model (defined in section 6.2). Lower values of P indicate a low probability of H_0 to be true, so H_0 will be refused and therefore the variable will be accepted as relevant. High values of P indicate a high probability of H_0 to be true, so H_0 will be accepted and therefore the variable will be concluded to be irrelevant. It has been agreed that P-values lower than 10%

[15] F. Dorey (2010). *In Brief: The P-Value: what is it and what does it tell you?* *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2895822/*

allow to refuse the null hypothesis (see Figure 27). Lower values than 5% will be considered as *very relevant* and values between 5% and 10% will be considered as *relevant.*

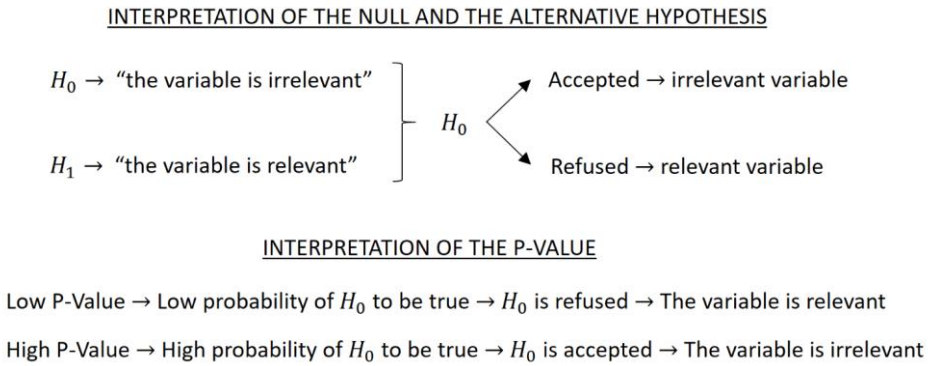


Figure 27. Interpretation of the hypothesis and the P-value.
Source: Own elaboration.

The output given by *Mplus* is: 1) the *Estimate*, that is, the estimated value for one of the k independent variables x, 2) the respective Standard Error (*S.E.*), 3) the quotient between the last two, 4) the P-value.

Various iterations have been made in order to refine de model. The results of the first iteration are shown below (Table 10):

MODEL FIT INFORMATION

Number of Free Parameters	31
Loglikelihood	
H0 Value	-176.779
Information Criteria	
Akaike (AIC)	415.558
Bayesian (BIC)	571.569
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	473.104

MODEL RESULTS (1st iteration)

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
MODE#1 ON				
WOMAN	-0.730	0.332	-2.197	0.028
DIFCOST	0.904	0.459	1.971	0.049
DURVP	-0.015	0.037	-0.400	0.689
DURMB	-0.003	0.012	-0.249	0.803
NMEMBERS	0.193	0.171	1.126	0.260

NTRIPS	0.473	0.131	3.609	0.000
TUESDAY	-0.609	0.535	-1.139	0.255
WEDNESD	-0.172	0.562	-0.307	0.759
THURSDAY	-0.770	0.573	-1.344	0.179
FRIDAY	-0.788	0.539	-1.462	0.144
R18TO44	-0.354	0.885	-0.400	0.689
R45TO64	0.012	0.955	0.013	0.990
R65TO79	0.853	1.321	0.645	0.519
MORE79	11.818	0.000	999.000	999.000
MORNING	0.201	0.356	0.565	0.572
AFTERN	0.804	0.457	1.761	0.078
NIGHT	0.372	1.110	0.335	0.737
STUDENT	-1.998	0.590	-3.384	0.001
DOMESTIC	-0.764	0.589	-1.299	0.194
NOTLOOK	11.472	0.000	999.000	999.000
LOOKING	-1.444	0.477	-3.027	0.002
RETIRED	-0.209	0.835	-0.250	0.802
PENSION	10.733	276.465	0.039	0.969
OTHERACT	6.916	0.000	999.000	999.000
NOSTUD	12.232	271.618	0.045	0.964
PRIMARY	-1.002	0.483	-2.073	0.038
SECOND	-0.080	0.514	-0.156	0.876
VT	-0.188	0.640	-0.294	0.769
OTHERSTU	-2.326	1.168	-1.991	0.046
ESTDK	-2.323	0.548	-4.236	0.000
Intercepts				
MODE#1	3.354	1.472	2.278	0.023

Table 10. Model results: first iteration.
Source: Own elaboration.

A great part of the variables have a high P-value: DURVP, DURMB, TUESDAY, WEDNESDAY, R18TO44, R45TO64, MORNING, NIGHT, RETIRED, PENSION, NOSTUD, SECOND, and VT. These variables are not relevant and will be removed from the code.

There are three variables that show an abnormal 999,000 value (MORE79, NOTLOOK and OTHERACT), which produce a singularity in the information matrix. In order to avoid this fact, values of such variables have been fixed by Mplus.

At the second iteration, variables that had the highest P-values in the first attempt are no longer in the model, as well as those that caused the singularity of the matrix. Results are shown below (Table 11):

MODEL FIT INFORMATION

Number of Free Parameters	15
Loglikelihood	
H0 Value	-183.673
Information Criteria	
Akaike (AIC)	397.347
Bayesian (BIC)	472.836
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	425.192

MODEL RESULTS (2nd iteration)

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
MODE#1 ON				
WOMAN	-0.720	0.319	-2.259	0.024
DIFCOST	0.677	0.233	3.906	0.004
NMEMBERS	0.174	0.162	1.075	0.282
NTRIPS	0.431	0.129	3.350	0.001
THURSDAY	-0.230	0.419	-0.549	0.583
FRIDAY	-0.462	0.401	-1.151	0.250
R65TO79	0.765	0.776	0.985	0.325
AFTERN	0.688	0.383	1.798	0.072
STUDENT	-1.971	0.434	-4.545	0.000
DOMESTIC	-0.632	0.562	-1.125	0.261
LOOKING	-1.522	0.451	-3.371	0.001
PRIMARY	-0.800	0.363	-2.206	0.027
OTHERSTU	-2.318	1.013	-2.288	0.022
ESTDK	-2.460	0.443	-5.548	0.000
Intercepts				
MODE#1	2.697	0.671	4.017	0.000

Table 11. Model results: second iteration.
Source: Own elaboration.

After some more iterations in which other irrelevant variables have been removed, the coefficients that have been obtained are the following:

MODEL FIT INFORMATION

Number of Free Parameters	10
Loglikelihood	
H0 Value	-186.033
Information Criteria	
Akaike (AIC)	392.066

Bayesian (BIC)	442.392
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	410.630

MODEL RESULTS (after various iterations)

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
MODE#1 ON				
WOMAN	-0.813	0.306	-2.654	0.008
DIFCOST	0.675	0.235	2.879	0.004
NTRIPS	0.463	0.127	3.648	0.000
AFTERN	0.659	0.379	1.741	0.082
STUDENT	-1.854	0.401	-4.617	0.000
LOOKING	-1.429	0.418	-3.423	0.001
PRIMARY	-0.751	0.346	-2.167	0.030
OTHERSTU	-2.174	1.024	-2.122	0.034
ESTDK	-2.218	0.405	-5.276	0.000
Intercepts				
MODE#1	2.997	0.5	5.998	0.000

Table 12. Model results after various iterations.
Source: Own elaboration.

Results show that almost all the variables that are left in the model are *very relevant* as their P-Value is lower than 5%, so it is possible to proceed to the interpretation.

6.3.3. Interpretation of the results

For interpreting the results of the model, run by Mplus, we must pay attention to the column *Estimate* in Table 12. As it has been reaffirmed along this work, results are referred to the dependent variable Metrobús (suburban bus). Hence, if the value at the column *Estimate* is positive, it means that the augmentation of a unit in a *continuous variable* affects favourably to the use of the suburban bus, and if it is negative it means that it contributes to the decrease of the demand of the suburban bus. In the case of *categorical variables* (whose response is 1 = "yes" and 0 = "no"), a positive coefficient means that if the response is "yes" it will affect favourably to the increase of the demand of Metrobús, and a negative value will indicate that a "yes" response will affect negatively to demand.

According to the value of the *Estimate* column, the interpretations of each variable are the following:

- For the variable WOMAN, the model shows that women tend to use the suburban bus less than men. This result, a priori, may seem illogical, as it has been demonstrated that women tend to use public transport more than men. However, we are working with a very specific sample: people who have the option of using their private vehicle and that are only served by suburban bus as public transport mode. A large proportion of those people who use public transport is *captive*; this means that they do not have the option to choose. Having selected in our sample the people who have the option to choose to travel with their private vehicle, we start from the basis that none of them are captive users. Results show that women, if they have the possibility to select whether to travel by car or by the suburban bus, they will tend to use their private vehicle.

- The variable DIFCOST has been defined as the difference between the cost of the trip made by the private vehicle and the cost of the trip made by Metrobús. A positive difference will mean that it is more expensive to travel by private vehicle than by suburban bus. Therefore, a positive coefficient means that the higher the difference between costs, the greater the demand of Metrobús will be.

- The NTRIPS variable expresses the number of trips per day that are made by each individual. A positive coefficient indicates that if the number of trips is higher, the demand of the suburban bus will grow. This result is illogical as public transport is mostly used for doing pendular displacements and not for multiple trips during a day with different origins and destinations. The variable is numerically relevant for the model but also is logically inconsistent. Thus, it has been decided to remove it from the model.

- AFTERN is a categorical variable that indicates if the trip has been made between 5:00 p.m. and 10:00 p.m. A positive coefficient indicates that during this slot people tend to use more the suburban bus.

- The results of the two following variables, STUDENT and LOOKING (for a job), have the same explanation as the variable WOMAN. Having the possibility to choose whether to use the private vehicle or the suburban bus, people will tend to use the first one.

- The three last variables, PRIMARY (*Primary studies*), OTHERSTUD (*Other Studies*) and STUDK (*Do not know which studies they have)*, indicate that the fact of having studies does not impact positively on the use of Metrobús.

As we have decided to remove the variable NTRIPS for eluding the logical contradiction that it entails, a new iteration has been made without this variable with the following results (Table 13):

MODEL FIT INFORMATION

Number of Free Parameters	9
Loglikelihood	
H0 Value	-194.444
Information Criteria	
Akaike (AIC)	406.888
Bayesian (BIC)	452.182
Sample-Size Adjusted BIC (n* = (n + 2) / 24)	423.595

MODEL RESULTS (final iteration)

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
MODE#1 ON				
WOMAN	-0.802	0.304	-2.641	0.008
DIFCOST	0.574	0.223	2.576	0.010
AFTERN	0.780	0.375	2.078	0.038
STUDENT	-1.966	0.396	-4.965	0.000
LOOKING	-1.255	0.415	-3.027	0.002
PRIMARY	-0.816	0.345	-2.265	0.018
OTHERSTU	-2.232	0.998	-2.238	0.025
ESTDK	-2.394	0.397	-6.027	0.000
Intercepts				
MODE#1	4.397	0.355	12.371	0.000

Table 13. Model results: final iteration.
Source: Own compilation.

Comparing Table 12 and Table 13, it can be observed that results are very similar; insignificant differences are due to the readjustment of the model.

As a preliminary conclusion, from Table 13 we sum up that there are eight relevant (and logically coherent) independent variables that have an influence in the choice of Metrobús as mode of transport (against the private vehicle, as results are relative). These eight variables are related to four categories: gender, cost (price), time slot and studies.

Our final objective is to come up with a tool that a transport company could use to make a technical decision for the implementation of new bus lines. That is why we are finally going to select the category of variable that shows an essential and pure technical nature, that is, the monetary cost understood as the relative price that an individual would have to pay for using the private vehicle against the alternative of travelling by Metrobús[16]. This cost could also be

[16] However, we do not forget that the public transport service is an essential tool for the local government in order to design his transport, environmental and regional planning policies. For this purpose, it would be useful to include

identified by the transport company as a clue for estimating a demand function and thus for determining a fare table.

Consequently, now we run again the code at Mplus for doing a new and last iteration considering only the variable DIFCOST (Table 14).

```
 MODEL FIT INFORMATION
Number of Free Parameters                        2
Loglikelihood
          H0 Value                         -227.835
Information Criteria
          Akaike (AIC)                      459.670
          Bayesian (BIC)                    469.736
          Sample-Size Adjusted BIC          463.383
            (n* = (n + 2) / 24)
```

MODEL RESULTS (conclusive iteration)

	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
MODE#1 ON				
DIFCOST	0.538	0.207	2.597	0.009
Intercepts				
MODE#1	3.082	0.164	18.809	0.000

Table 14. Model results: conclusive iteration.
Source: Own elaboration.

The results of the conclusive iteration are the ones that we will apply in the Logit model, being β_0 = -3,082[17] and β_1 = 0,538 the beta-factor linked to the sole independent variable affecting the dependent variable. It should be remembered that the utility function that relates parameters and variables is (Eq. 4):

the whole set of variables. This idea could be considered in further developments of this Final Master's Degree Project.

[17] Mplus provides the value of the parameter β_0 with the opposite sign, so it has been changed to negative for calculating the utility associated to the use of Metrobús.

$$V_{jq} = \beta_{0j} + \sum_{k} \beta_{kj}\ x_{kjq} \xrightarrow[j=Metrobús]{\substack{k=1 \\ q \rightarrow certain\ individual}} V_{Metrobús} = \beta_0 + \beta_1 \cdot x_1 \qquad \text{(Eq. 12)}$$

where j is the mode of transport (Metrobús), q is the individual who makes a certain trip, k the number of independent variables at the model and x_1 is the difference between costs of the private vehicle and the suburban bus.

Then, as a result of the appliance of the values obtained at the conclusive iteration of the model, we obtain the next expression of the utility associated to the use of Metrobús for a certain individual:

$$V_{Metrobús} = -3{,}082 + 0{,}538 \cdot DIFCOST \qquad \text{(Eq. 13)}$$

As it has been exposed in section 6.3.1, note 4, estimations in the model are calculated for the Metrobús-mode with respect to the private vehicle-mode. Then (Eq. 11) (at section 6.1), which gives the probability for a certain individual of using Metrobús, must be rewritten as follows:

$$P(j) = \frac{1}{1 + e^{-(V_j - V_i)}} \quad \rightarrow \quad P(Metrobús) = \frac{1}{1 + e^{-(V_{Metrobús})}} \qquad \text{(Eq. 14)}$$

Therefore, the right part of Eq. 14 is the one that will be used for analysing a hypothetical new suburban bus line at the south region of the Metropolitan Area of Valencia in order to estimate the demand. For doing so, we will follow the next steps:

1) Delimitation of the area of study.
2) Analysis of the trips at the area of study.
3) Metrobús new service proposal on the map.
4) Application of the Logit model.
5) Time table of the new line.
6) Economic analysis of the proposal.

7. Application for implementing a new Metrobús line

Now, the question should be addressed from the point of view of the transport company that would operate a new Metrobús line. This leads to take into account different aspects related to economic efficiency, as such company is supposed a private corporation that aims for monetary benefits. However, the enterprise's objective must be compatible with the user's interests; this is the main reason why it should be convenient to analyse different proposals. And so we do, designing two new Metrobús lines: the first one is longer, more time consuming and costlier but also higher in demand and so higher in potential economic benefits; the second one is shorter, less time consuming and cheaper but less financially profitable.

We will continue exposing both solutions.

7.1. Solution number 1

7.1.1. Delimitation of the area of study

After developing the discrete choice Logit model and obtaining the associated probability function, it is possible to calculate the potential demand that a new suburban bus line would have depending on the cost of the trip. The first step towards the implementation of a new line consists on the identification of a zone with no public transport service but with high mobility flows.

As explained in section 5.1, there are important mobility flows between municipalities at the Metropolitan Region of Valencia which are not served by any public transport network. Specifically, at the south part of the region it has been identified a zone poorly connected by public transport and which includes the axe conformed by the municipalities of Torrent, Picanya and Paiporta (West axe) and the axe containing the nucleuses of Benetússer, Alfafar, Massanassa, Catarroja and Albal (East axe), which are only mutually connected by one suburban bus line between Paiporta and Benetússer. Thus, the great majority of displacements between the two axes are made by private vehicle, as it happens to be the optimal option at this moment. For example, as it can be seen in Figure 28, currently there are two options for travelling by public transport between Catarroja and Torrent: 1) the first one would involve taking the suburban railway network to the north until the centre of Valencia, and then transfer to the subway network for going back to the Southwest to get to Torrent; 2) the second one would consist on taking the suburban railway from Catarroja to Benetússer, transferring to the suburban bus from Benetússer to Paiporta and then taking the subway from Paiporta to Torrent. For both options, in terms of economy and time the car is better than the public transport alternatives.

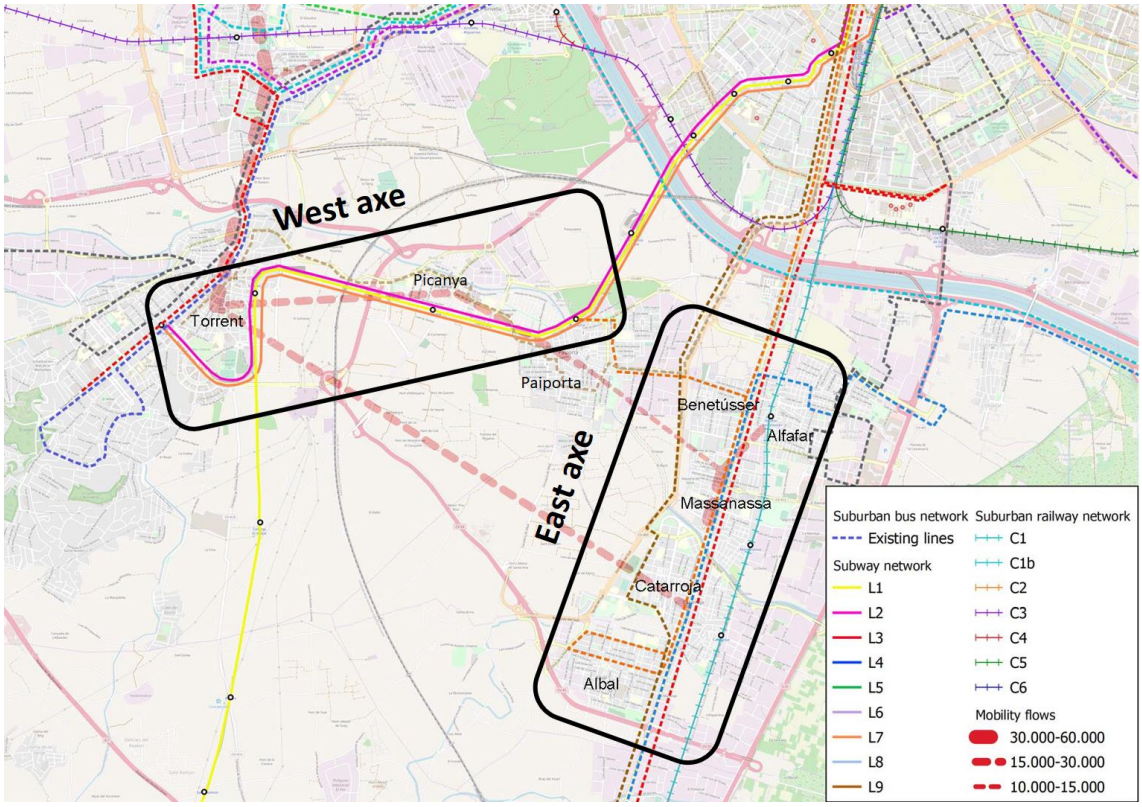
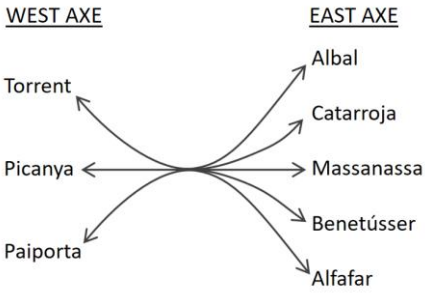


Figure 28. South region of the Metropolitan Area of Valencia and public transport supply.
Source: Own elaboration.

Figure 29 illustrate the set of possible origins and destinations between the two axes[18].



Torrent_Albal	Picanya_Albal	Paiporta_Albal
Torrent_Catarroja	Picanya_Catarroja	Paiporta_Catarroja
Torrent_Massanassa	Picanya_Massanassa	Paiporta_Massanassa
Torrent_Benetússer	Picanya_Benetússer	Paiporta_Benetússer
Torrent_Alfafar	Picanya_Alfafar	Paiporta_Alfafar
Albal_Torrent	Albal_Picanya	Albal_Paiporta
Catarroja_Torrent	Catarroja_Picanya	Catarroja_Paiporta
Massanassa_Torrent	Massanassa_Picanya	Massanassa_Paiporta
Benetússer_Torrent	Benetússer_Picanya	Benetússer_Paiporta
Alfafar_Torrent	Alfafar_Picanya	Alfafar_Paiporta

Figure 29. Set of possible origins and destinations at Solution 1.
Source: Own elaboration.

[18] It should be noted that trips *along* the West axe and *along* the East axe can be done by subway or by the suburban train, so these trips have not been included in the analysis, and therefore the associated demand is not a variable to be taken into consideration.

The East axe has wide industrial estates (IE) that are a source of a great amount of obligated mobility flows. Specifically, the industrial areas of "Massanassa" and "El Bony" are located at this zone. Furthermore, it exists a large commercial area with big department stores such as IKEA, Carrefour, MediaMarkt, Leroy Merlin, Lidl, Worten, Toys'R'Us, Porcelanosa, Decathlon or the shopping mall MN4, among others; these concentration of stores attracts a large number of people. In addition, the university campus and educational centre of La Florida is located in Catarroja, so students will also make daily trips to this zone. Figure 30 shows the location of these establishments.

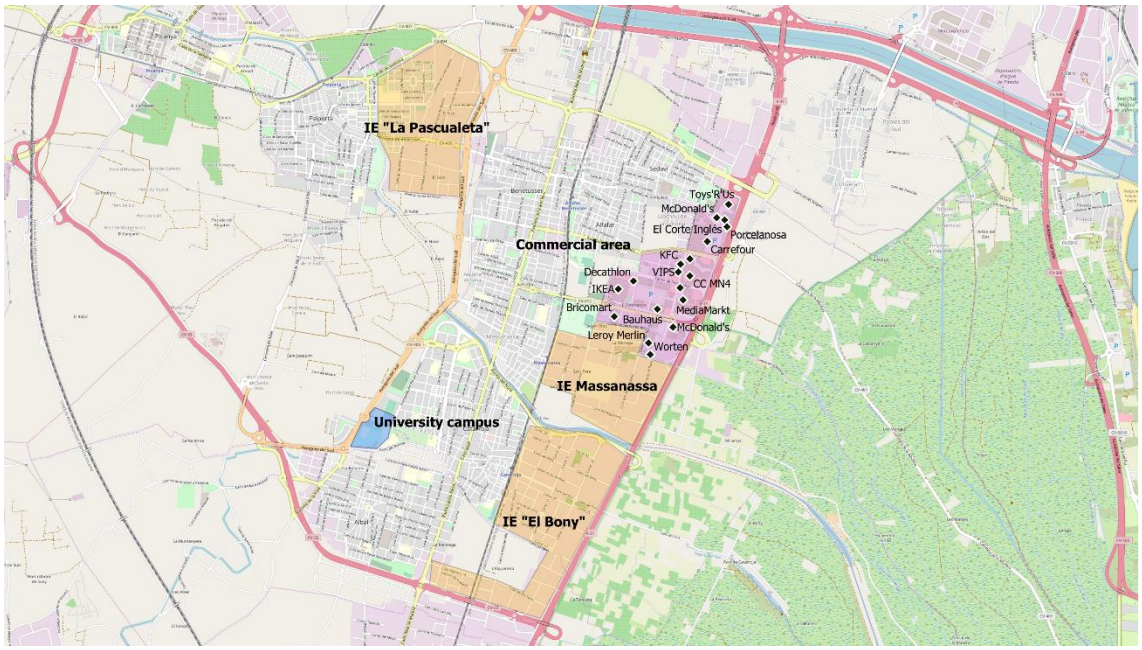


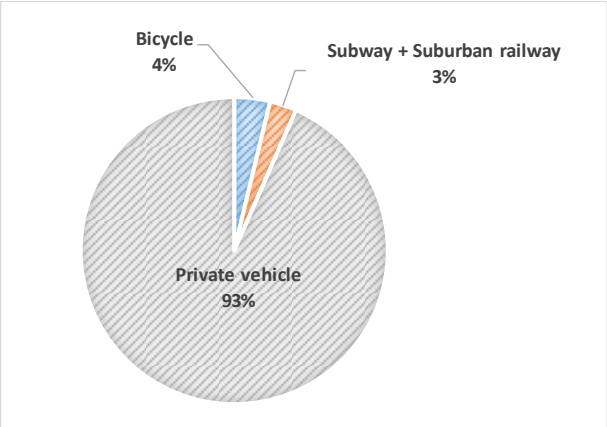
Figure 30. Commercial and Industrial States in the East axe.
Source: Own elaboration.

The potential demand of the new bus service is composed of: a) pendular trips between industrial areas, commercial and educational establishments and the residential zones of Torrent, Picanya and Paiporta; b) mobility flows from the West axe to the East axe in the morning, as passengers should do a trip to get from their house to their work place or their educational centre; c) afternoon trips with the East axe as origin and Torrent, Picanya and Paiporta as destination, as people go back home after having finished their working day.

For going forward with a detailed analysis, trips between the West axe and the East axe have been identified at the trips data-matrix (from section 2 of this work) and isolated in a new matrix called *Solution 1 Matrix*.

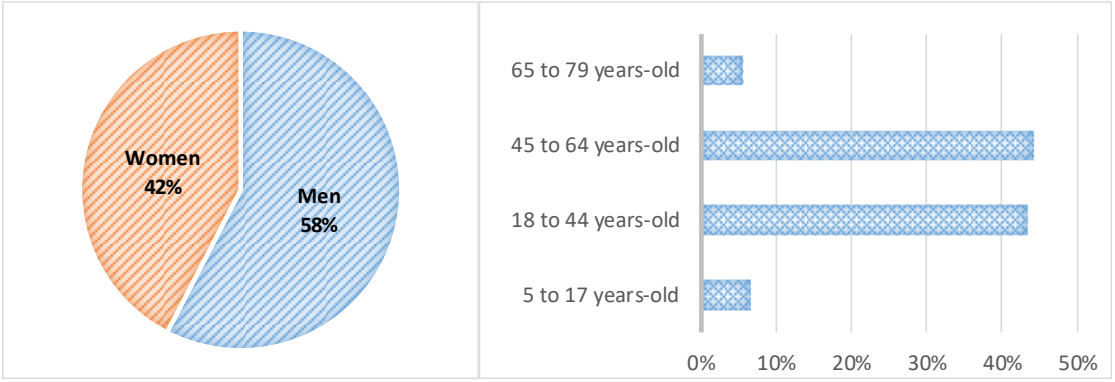
7.1.2. Analysis of the trips at the area of study

The total number of trips per day in the area of study is 10.338, and the respective modal split (shown in Graph 14) illustrates a 93% share corresponding to the private vehicle. Only 3% of the passengers use a combination of the subway and the suburban railway to get to their destination. The 4% left corresponds to bicycle users.



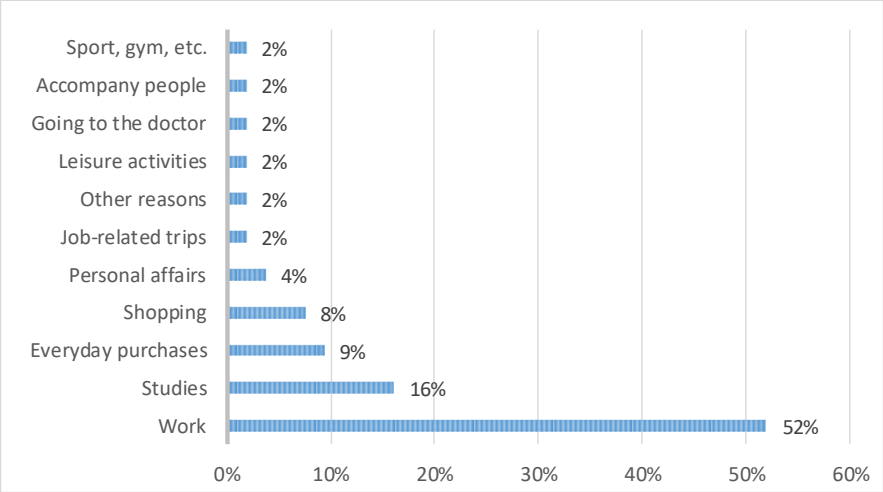
Graph 14. Actual modal split at the area of study (Solution 1).
Source: Own elaboration.

The proportion between women and men that take the private vehicle, which is the most representative mean of transport, is 42% women against 58% men. The range of age that does the larger percentage of trips are those passengers between 45 and 64 years-old (44%) and between 18 and 44 years-old (43%). The youngest and eldest sector of the population only represent a 13% between the both of them.



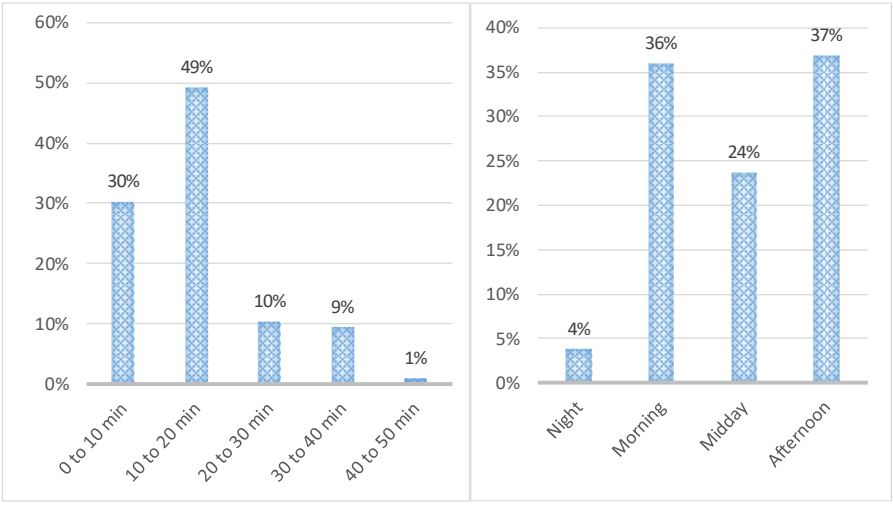
Graph 15. Gender and age distribution of private vehicle users (Solution 1).
Source: Own elaboration.

The two predominant reasons for making a trip are due work (52%) and studies (16%). As it has been explained, the East axe has big industrial and commercial areas, and also counts with the university and educational centre of La Florida, so results are coherent with the existent establishments, as well as with the age distribution.



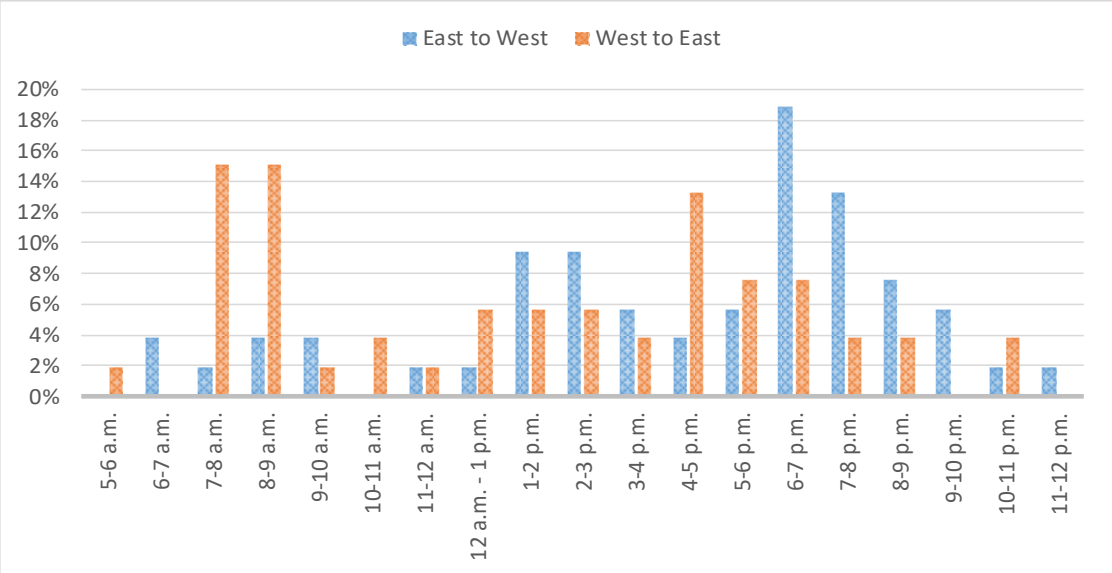
Graph 16. Reasons for making a trip at the area of study (Solution 1).
Source: Own elaboration.

Graph 17 shows the distribution of the duration of trips and the time of day in which trips are made. The average duration is 16,7 minutes. The distribution of trips depending on the time of day is compensated between the morning (3.706 trips) and the afternoon (3.803 trips). At midday, there is also an important demand of 2.438 passengers.



Graph 17. Distribution of durations of trips (left) and number of trips depending on the time slot (right) (Solution 1).
Source: Own elaboration.

A more detailed analysis of the distribution of trips along the day is shown in Graph 18. There are peaks of displacements between 7:00 a.m. and 9:00 a.m. going from the West axe to the East axe, and between 6:00 p.m. and 7:00 p.m. from the East axe to the West axe.



Graph 18. Distribution of trips per hours (Solution 1).
Source: Own elaboration.

As it had been expected, there is a peak of displacements in the morning going from the West to the East axe (that is, from Torrent, Picanya and Paiporta to the industrial and commercial areas). It also exists a great number of trips in this same direction at the beginning of the afternoon (between 4:00 p.m. and 5:00 p.m.), which may be due to people going shopping to the commercial centre. Trips between the West axe to the East axe get reduced by the end of the day.

In the opposite direction, there is a small number of trips being made in the morning. At midday, the number of passengers increases: the morning working shift is ended and some workers or students may go back home. The greatest peak of displacements with the East axe as an origin and the West axe as destination is between 6:00 p.m. and 8:00 p.m., which corresponds to the time when industries close. Between 8:00 p.m. and 10:00 p.m. there still are some trips being done, which may be due to workers of the commercial zone and clients.

Finally, the reasons of passengers for not choosing the public transport and using their private vehicle are indicated at the next table:

REASONS AGAINST THE USE OF THE PUBLIC TRANSPORT	
There is no public transport service or it is inappropriate	78%
It is not comfortable	6%
Price	4%
Other reasons	4%
I do not know about the public transport service	2%
Low frequency	2%
Inappropriate schedule	2%
Too slow	2%

Table 15. Reasons for not using public transportation (Solution 1). Source: Own elaboration.

The main reason that passengers give for not using the public transport is that there is no service or that it is inappropriate (78%). This result is as expected: the lack of public transport service between axes leaves no other option rather than using the private vehicle.

7.1.3. Metrobús new service proposal on the map

Our objective in this subsection is to define a new Metrobús line route on the map, with the following requirements:

- The route should properly link the West axe and the East axe, the one with the other.
- The route should connect the residential areas with the industrial estates, commercial and educational zones.
- The route should pass through the largest number of zones that are a source of the greatest number of displacements.
- The route should offer appropriate and safe areas for a bus-stop.
- The route should avoid narrow streets and should try to cross municipalities only by main streets[19].

Combining this set of requirements, we have come up with the solution printed in Figure 31. The itinerary is circular and has a total of 13 stops (blue dots at the figure): Torrent, Florida, Catarroja-South, IE El Bony, Catarroja-North, Massanassa, IKEA, MN4, Alfafar, Benetússer, IE Pascualeta, Paiporta and Picanya. The departure is made at an open space in the entrance of Torrent (a large residential city); after exiting the urban nucleus, it passes through a vast agricultural territory ("huerta valenciana") along seven kilometres, reaching the border line

[19] The track has been checked with the aid of the *Google Maps' Street View* for confirming its appropriateness driving a bus.

between Albal and Catarroja, very near to entrance of the Florida University and Educational Centre (important study point); going on, the bus would get to the wide industrial zone of *El Bony* (which could be the destination of a lot of workers); from there, the bus will cross principal streets of Massanassa heading to one of the greatest commercial hubs of the Metropolitan Area of Valencia (where many people go shopping to big department stores like IKEA, Carrefour, Decathlon, etc.); going out from the commercial zone, the bus will run towards Alfafar and Benetússer (very populated towns) before arriving to the industrial area of *La Pascualeta*; the route continues through Paiporta and Picanya (orange productors) and reaches the departure point at Torrent.

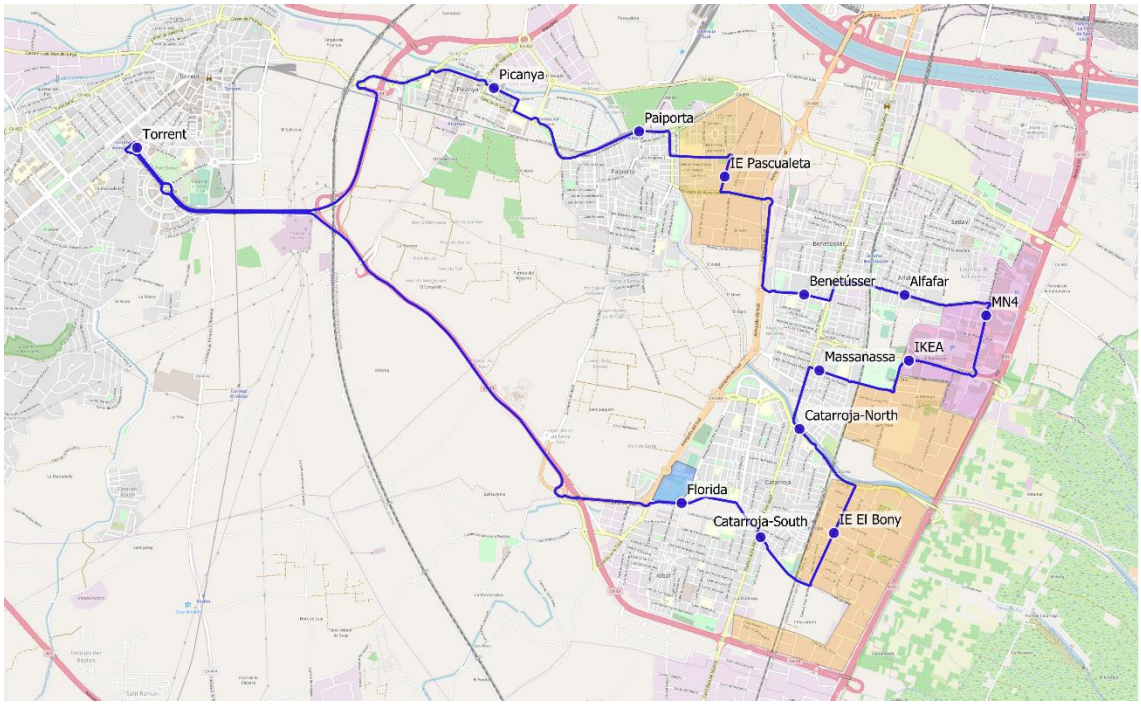


Figure 31. Proposal of Metrobús line (Solution 1) with 13 stops (blue dots).
Source: Own elaboration.

The average travel time for completing the whole round is an hour.

7.1.4. Application of the Logit model

In previous subsections we have delimitated the area of study (7.1.1), we have described the trips that are made between the possible origins and destinations (7.1.2), and we have defined the itinerary of our new line (7.1.3). Now, it is time to apply the Logit model described in section 6.3 in order to calculate the probability for a person of travelling with Metrobús.

For doing so, it is firstly necessary to obtain the generic costs associated to the alternative transport mode: the private vehicle. This cost has been calculated with the same method applied in subsection 5.3.4: on the one hand, the cost of fuel per litre is considered as the average between the costs of diesel and gasoline in Spain: 1,169 €/litre; on the other hand, it has been considered a mean consumption of 6 litres of carburant per 100 kilometres and an average speed of 65 kilometres per hour. Then the cost, which will depend on the duration of the trip, can be calculated as follows:

$$Cost\ [€] = duration\ [min] \cdot 1{,}169\ \left[\frac{€}{l}\right] \cdot \frac{6}{100}\ \left[\frac{l}{km}\right] \cdot \frac{65}{60} \cdot \left[\frac{km}{min}\right] \quad \text{(Eq. 15)}$$

Secondly, to estimate the cost of the trip using Metrobús, we consider the current fare prices. Nowadays, people can use a transport card for using the Metrobús within princing zones A and B[20] that allows one transfer between Metrobús, the subway network and the bus networking during 90 minutes after the first validation of the ticket. It costs 15,50€ for 10 tickets. Therefore, it has been considered an individual cost of 1,55 euro per trip in case of using Metrobús, no matter the distance or the travel time of the displacement.

Thus, the difference of costs between the two modes of transport will only depend on the duration of the trip in case the displacement was done by the private vehicle, and can be expressed as follows:

$$DIFCOST = duration\ [min] \cdot 1{,}169\ \left[\frac{€}{l}\right] \cdot \frac{6}{100}\ \left[\frac{l}{km}\right] \cdot \frac{65}{60} \cdot \left[\frac{km}{min}\right] - 1{,}55\ [€] \quad \text{(Eq. 16)}$$

Having obtained an expression for calculating the difference between costs, it is possible to estimate the probability of the passenger of using Metrobús with (Eq. 11).

For example, for a hypothetical 16,7-minute trip made by private vehicle (which is the average time travel at this zone obtained in subsection 7.1.2), the difference of costs would be:

$$DIFCOST = 16{,}7\ [min] \cdot 1{,}169\ \left[\frac{€}{l}\right] \cdot \frac{6}{100}\ \left[\frac{l}{km}\right] \cdot \frac{65}{60} \cdot \left[\frac{km}{min}\right] - 1{,}55\ [€] = 1{,}27 - 1{,}55 = -0{,}28\ €$$

Then, for this example, the probability of using Metrobús would be calculated as follows:

[20] Our area of study (West axe and East axe) is located at these pricing zones.

$$V_{Metrobús} = -3{,}082 + 0{,}538 \cdot DIFCOST = -3{,}082 + 0{,}538 \cdot (-0{,}28) = -3{,}2332$$

$$P(Metrobús) = \frac{1}{1 + e^{-(V_{Metrobús})}} = \frac{1}{1 + e^{3{,}2332}} = 0{,}038 \rightarrow 3{,}8\ \%$$

The probability of using Metrobús would be 3,8%

This same calculation process has been applied for each of the trips at the *Solution 1 Matrix*: the average probability of using Metrobús at the area of study is 4,08% for an individual. This means that, being 10.338 the total number of trips made at the area under study, the average number of trips that would be made by Metrobús is the 4,08% of this amount, that is, 422 trips per day. This number represents the potential daily demand of a new Metrobús line at such area.

7.1.5. Time table of the new line

For planning the schedules for our new Metrobús line, it is essential to know how the potential demand at each hour of the day is distributed in order to determine the number of buses that will be needed, as well as their frequency.

Graph 18 (in subsection 7.1.2) exposed the percentage of trips that were made at each hour of the day considering the total number of displacements that are made between the West axe and the East axe, which are 10.338 (as we have seen in such subsection, 90% of these displacements are nowadays made by the private vehicle). Now, we will use this same distribution for obtaining the total number of trips at each hour of the day that would be made by Metrobús considering a demand of 422 people (Table 16 and Graph 19).

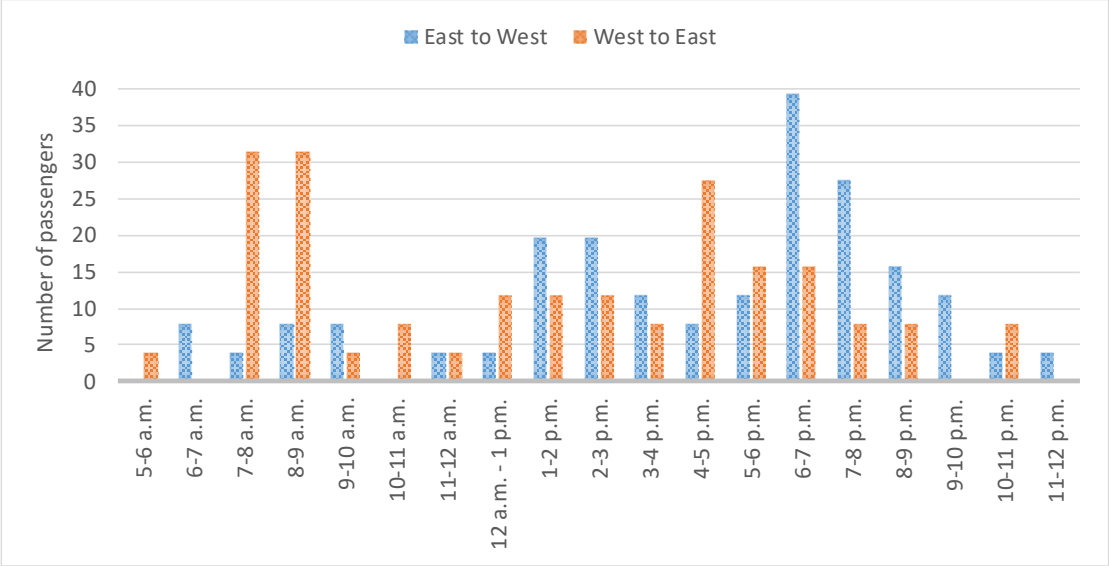
HOURLY DISTRIBUTION OF POTENTIAL DEMAND

	East to West		West to East	
	(1)	(2)	(1)	(2)
5:00 a.m. - 6:00 a.m.	0%	0	2%	4
6:00 a.m. - 7:00 a.m.	4%	8	0%	0
7:00 a.m. - 8:00 a.m.	2%	4	15%	31
8:00 a.m. - 9:00 a.m.	4%	8	15%	31
9:00 a.m. - 10:00 a.m.	4%	8	2%	4
10:00 a.m. - 11:00 a.m.	0%	0	4%	8
11:00 a.m. - 12:00 a.m.	2%	4	2%	4
12:00 a.m. - 1:00 p.m.	2%	4	6%	12
1:00 p.m. - 2:00 p.m.	9%	20	6%	12

2:00 p.m. - 3:00 p.m.	9%	20	6%	12
3:00 p.m. - 4:00 p.m.	6%	12	4%	8
4:00 p.m. - 5:00 p.m.	4%	8	13%	28
5:00 p.m. - 6:00 p.m.	6%	12	8%	16
6:00 p.m. - 7:00 p.m.	19%	39	8%	16
7:00 p.m. - 8:00 p.m.	13%	28	4%	8
8:00 p.m. - 9:00 p.m.	8%	16	4%	8
9:00 p.m. - 10:00 p.m.	6%	12	0%	0
10:00 p.m. - 11:00 p.m.	2%	4	4%	8
11:00 p.m. - 12:00 p.m.	2%	4	0%	0

(1) % trips out of the total; (2) Number of trips

Table 16. Hourly distribution of potential demand of Metrobús per axes.
Source: Own elaboration.



Graph 19. Distribution of potential Metrobús trips per hours along the day (Solution 1).
Source: Own elaboration.

From the West axe to the East axe there would be a peak of trips in the morning, between 7:00 a.m. and 9:00 a.m., which should correspond to employees going to their working place at the beginning of the day (more than 30 passengers per hour). In this same direction, there would be a big number of displacements at the beginning of the afternoon (between 4:00 p.m. and 5:00 p.m.), which would get reduced but still high at the next hours, and that might correspond to people going shopping to the commercial zone. For this reason, the frequency of the bus at these hours should be higher.

From the East axe to the West axe, the first peak would be produced at midday, probably due to the end of the morning shift. However, the highest number of passengers would be registered between 6:00 p.m. and 8:00 p.m., when industries and shops close. Again, the communication of industrial estates and commercial spaces with residential zones should be higher during these hours.

Thus, the next schedule is proposed for the new suburban bus line:

Torrent	Florida	Catarroja - South	I.E. "El Bony"	Catarroja - North	Massanassa	IKEA	MN4	Alfafar	Benetússer	I.E. la Pascualeta	Paiporta	Picanya	Torrent
7:00	7:08	7:11	7:14	7:18	7:21	7:25	7:29	7:32	7:37	7:41	7:46	7:51	8:00
7:30	7:38	7:41	7:44	7:48	7:51	7:55	7:59	8:02	8:07	8:11	8:16	8:21	8:30
8:00	8:08	8:11	8:14	8:18	8:21	8:25	8:29	8:32	8:37	8:41	8:46	8:51	9:00
8:30	8:38	8:41	8:44	8:48	8:51	8:55	8:59	9:02	9:07	9:11	9:16	9:21	9:30
9:30	9:38	9:41	9:44	9:48	9:51	9:55	9:59	10:02	10:07	10:11	10:16	10:21	10:30
10:30	10:38	10:41	10:44	10:48	10:51	10:55	10:59	11:02	11:07	11:11	11:16	11:21	11:30
12:30	12:38	12:41	12:44	12:48	12:51	12:55	12:59	13:02	13:07	13:11	13:16	13:21	13:30
13:00	13:08	13:11	13:14	13:18	13:21	13:25	13:29	13:32	13:37	13:41	13:46	13:51	14:00
13:30	13:38	13:41	13:44	13:48	13:51	13:55	13:59	14:02	14:07	14:11	14:16	14:21	14:30
14:00	14:08	14:11	14:14	14:18	14:21	14:25	14:29	14:32	14:37	14:41	14:46	14:51	15:00
14:30	14:38	14:41	14:44	14:48	14:51	14:55	14:59	15:02	15:07	15:11	15:16	15:21	15:30
16:30	16:38	16:41	16:44	16:48	16:51	16:55	16:59	17:02	17:07	17:11	17:16	17:21	17:30
17:30	17:38	17:41	17:44	17:48	17:51	17:55	17:59	18:02	18:07	18:11	18:16	18:21	18:30
18:00	18:08	18:11	18:14	18:18	18:21	18:25	18:29	18:32	18:37	18:41	18:46	18:51	19:00
18:30	18:38	18:41	18:44	18:48	18:51	18:55	18:59	19:02	19:07	19:11	19:16	19:21	19:30
19:00	19:08	19:11	19:14	19:18	19:21	19:25	19:29	19:32	19:37	19:41	19:46	19:51	20:00
19:30	19:38	19:41	19:44	19:48	19:51	19:55	19:59	20:02	20:07	20:11	20:16	20:21	20:30
20:00	20:08	20:11	20:14	20:18	20:21	20:25	20:29	20:32	20:37	20:41	20:46	20:51	21:00

Table 17. Metrobús schedule for Solution 1.
Source: Own elaboration.

The schedule has been defined for absorbing the demand for each hour and direction. The travel time for doing a whole round of 25,3 kilometres is 1 hour, so it would be necessary to have 2 buses, as the frequency is up to 30 minutes during peak hours. The total number of rounds that will be made per day is 18.

The service would be given seven days a week. The demand is considered constant at every day of the week: during weekdays, industrial estates will be a source of a great part of displacements; during weekends, even though trips to industrial areas were reduced, the number of people going to commercial areas highly augments.

7.1.6. Economic analysis of the proposal

In this last section for Solution 1, an economic analysis of the proposed Metrobús line is presented in order to assess the financial profitability.

The new suburban bus line has 25,3 kilometres. There will be made 18 rounds per day, so the total number of kilometres per day will be 455,4. In a year, the number of travelled kilometres will be 166.211. Taking into account that there will be two buses available, each of them will travel 83.110,5 kilometres per year.

Each round takes an hour to be completed. Taking into account resting periods and a margin for taking the bus to the first station of the line and for going back to the parking lot in the afternoon, the total number of hours worked per day by the set of all employees of the line is 30. Then, in a year (365 days), the total number of hours worked is 10.950 (5.475 per bus).

For obtaining the personal costs, the Valencian Collective Agreement of the Road Transport of Passenger's Sector has been consulted (Provincial Official Bulletin, BOP, nº 248, 29/12/2017). The maximum number of hours that an employee can do per year is 1.768. In consequence, we will need a total of 10.950/1.768 ≈ 6 employees for making the service possible.

The minimum salary established by the Collective Agreement was set in 21.077,23 euro per year in 2017. The document assures an augmentation of 1,8% of the salary in 2018 and of a 2% in 2019. Then, in 2019 the minimum salary would be 21.885,75 euro. In addition, drivers get a bonus of 6,5 euro per day if tickets can be bought inside the bus and a bonus of 1,18 euro per day due to the *quebranto de moneda*[21]. Considering the same salary augmentation, the total amount received per year in bonus is 1.882,00 euro. Knowing that 6 employees will be needed, the total personal costs will be 131.314,5 euro in terms of salary (65.657,25 euro per bus) and 11.292 euro in terms of bonus (5.646 euro per bus).

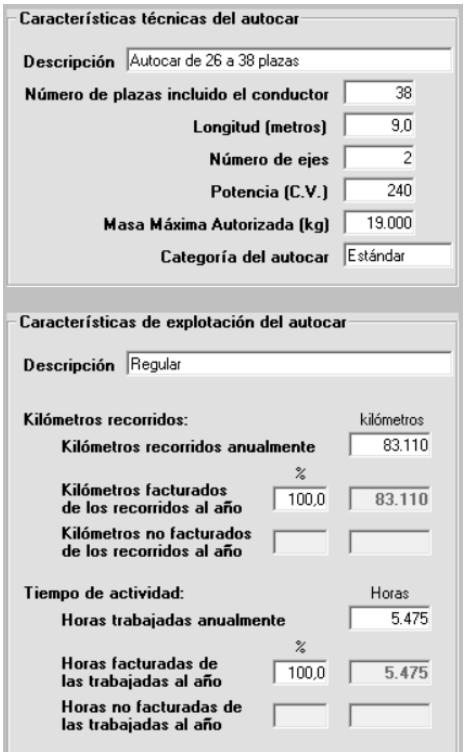
The global economic analysis has been made with the aid the ACOTRAVI, which is a software provided by the Spanish Ministry of Development for calculating the operating costs of passenger buses. The program integrates a cost database elaborated at the Observatory of the Costs of Passenger Transport by Bus by the Spanish National Committee of Road Transport and

[21] At the end of the day, drivers have to hand the money collected in tickets to the company. In case the amount that is given does not correspond with what has been sold, workers have to pay the difference with their own money. The *quebranto de moneda* bonus is given in compensation.

the General Directorate of Road Transport; this database is updated each six months, and the last one available is from the 01-01-2019.

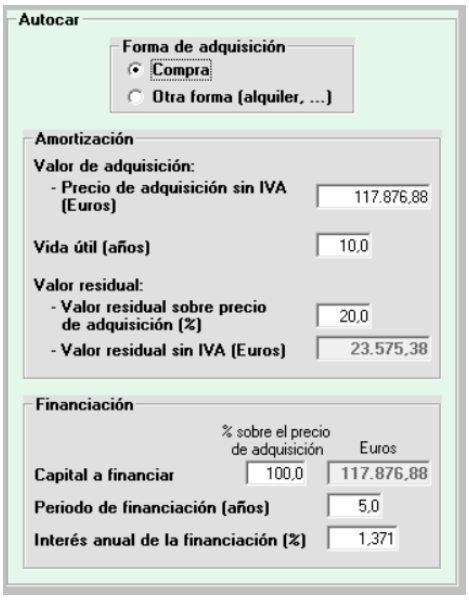
In ACOTRAVI, the first thing to do is to choose the type of bus that should be used according to its capacity. In this case, the most suitable model corresponds to a bus where there can be installed between 26 to 38 seats, driver included. We will choose a bus with 38 seats.

The output of ACOTRAVI is the following:



1) **Technical and operational characteristics**, which contains the following information:

   - Number of seats: 38
   - Length (metres): 9,0
   - Number of axles: 2
   - Horsepower (C.V.): 240
   - Maximum Authorized Mass (kg): 19.000
   - Category of the bus: Regular
   - Kilometres travelled per year: 83.110
   - Billed kilometres per year: 100%; 83.110
   - Hours worked per year: 5.475
   - Billed hours per year: 100%; 5.475



2) **Amortization and financing**

   a) Form of acquisition: purchase

   b) Amortization:
      - Acquisition value without tax (€): 117.876,88
      - Lifespan (years): 10
      - Residual value on acquisition price (%): 20
      - Residual value without tax (€): 23.575,38

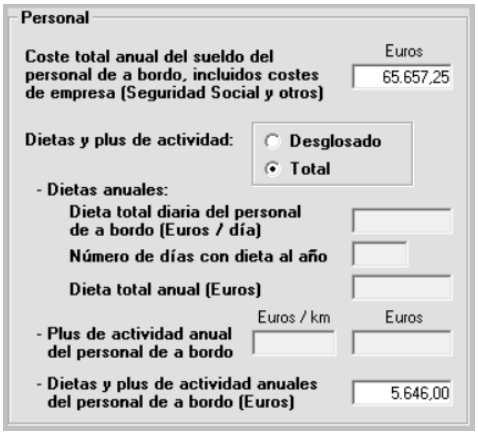
   c) Financing:
      - Capital to be financed: 100%; 117.876,88 €
      - Financing period (years): 5
      - Annual interest (%): 1,371

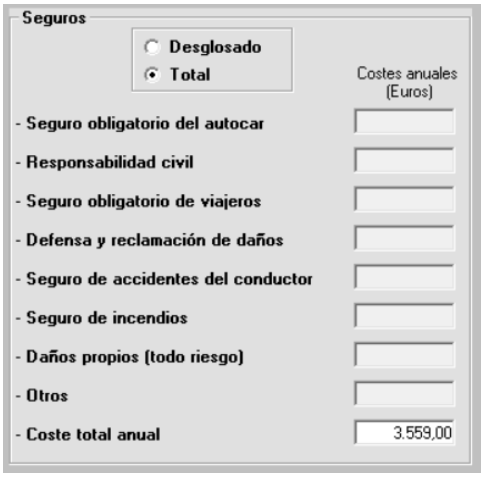
3) Personnel, insurance and fiscal costs

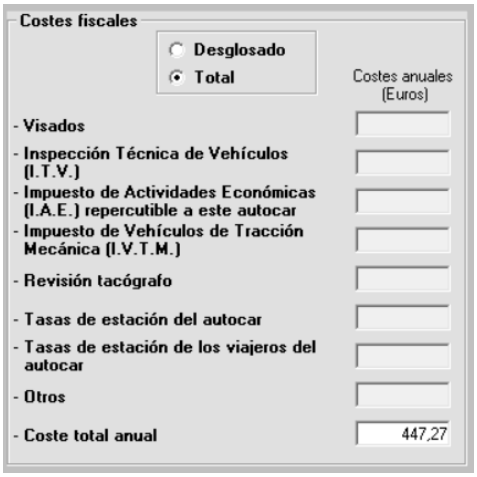
a) Personnel
- Annual salary (€): 65.657,00
- Annual bonus (€): 5.646,00

b) Insurance
- Total cost (€): 3.559,00

c) Fiscal costs
- Total cost (€): 447,27







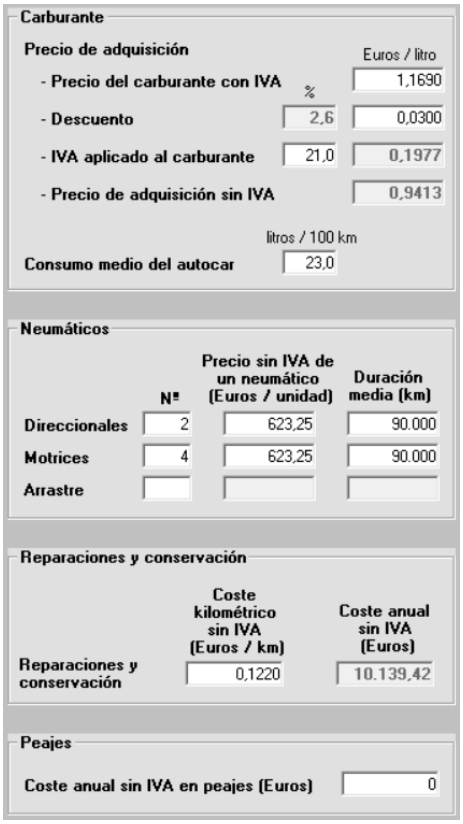
4) Variable costs

a) Fuel
- Cost with tax (€/l): 1,169
- Discount: 2,6%; 0,03 €/l
- Tax: 21%; 0,1977 €
- Final cost with tax (€/l): 0,9413
- Average consumption (l/100 km): 23

b) Tyres
- Directional tyres: 2 units; 623,25 €/unit; duration: 90.000 km
- Axle tyres: 4 units; 623,25 €/unit; duration: 90.000 km

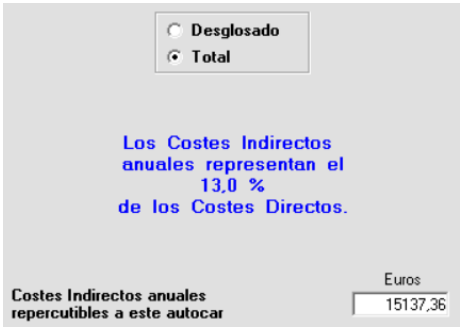
c) Repairs
- Total: 0,1220 €/km; 10.139,42 €/year

d) Tolls
- Total: 0 €



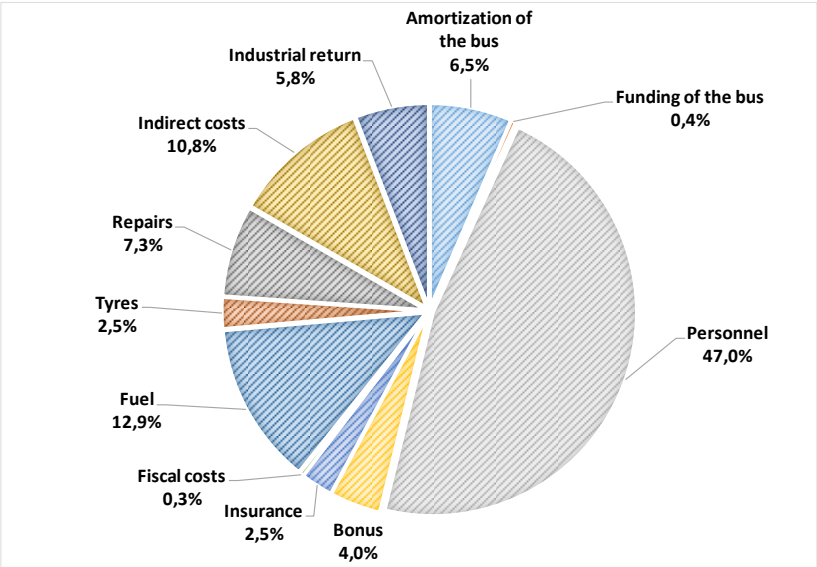
5) Indirect costs

a) Indirect costs (structure, marketing and others) = 13% of the direct costs: 15.137,36 €



6) Results

ANNUAL COSTS	Euro (€)	%
Total costs chargeable to all services	**139.729,50**	**100,0**
Direct costs	**116.441,25**	**83,3**
- Temporary costs	**84.854,95**	**60,7**
Amortization of the bus	9.056,20	6,5
Funding of the bus	489,23	0,4
Personnel	65.657,25	47,0
Bonus	5.646,00	4,0
Insurance	3.559,00	2,5
Fiscal costs	447,27	0,3
- Kilometric costs	**31.586,30**	**22,6**
Fuel	17.993,66	12,9
Tyres	3.453,22	2,5
Repairs	10.139,42	7,3
Tolls	0,00	0,0
Indirect costs (13% of direct costs)	**15.137,36**	**10,8**
Industrial return (7% of direct costs)	**8.150,89**	**5,8**



Graph 20. Costs distribution for Solution 1.
Source: Own elaboration based on the results obtained at ACOTRAVI.

The total cost of one bus per year is 139.729,50 euro, including indirect costs of 13% of the direct costs and an industrial return of 7% of the direct costs. For implementing our proposal, it is necessary to use two buses, so the total cost per year would be the double, that is, 279.459,00 euro.

The potential daily demand that has been calculated in section 7.1.4 is 422 passengers a day for a 1,55-euro ticket. The total number of passengers per year, considering a constant demand of passengers along each day of the year, is 154.030. The annual income is obtained by multiplying the number of passengers per year and the cost of a ticket, 1,55 x 153.030 = 238.746,5 euro.

Then, the annual balance of the service would be 252.863,16 - 238.879,50 = -40.712,50 euro (14,5% of total costs). Even though the balance is negative, the project is considered necessary in terms of social profitability; thus the local government should economically contribute with this quantity for being able to implement this solution and for avoiding that the transport company would incur in losses. Nowadays, the average percentage that the Valencia government gives with respect to the total of the costs of the lines is 30%. In consequence, we consider that this solution, with a 14,5% deficit, provides results that are good enough in comparison with the global situation that exists nowadays.

Dividing the total cost per year with the total number of passengers per year, it is obtained the price of the ticket from which the transport company would have positive economic results (break-even point), which is 1,81 euro per passenger.

7.2. Solution number 2

7.2.1. Delimitation of the area of study

The solution number 1 studied earlier offers a long service (25,3 km in 1 hour) between a total of eight municipalities. However, it should be convenient to study a less time consuming and cheaper to implant option. It would consist on a route connecting Torrent with Albal, Catarroja, Massanassa, Benetússer and Alfafar.

The set of possible origins and destinations are the following:

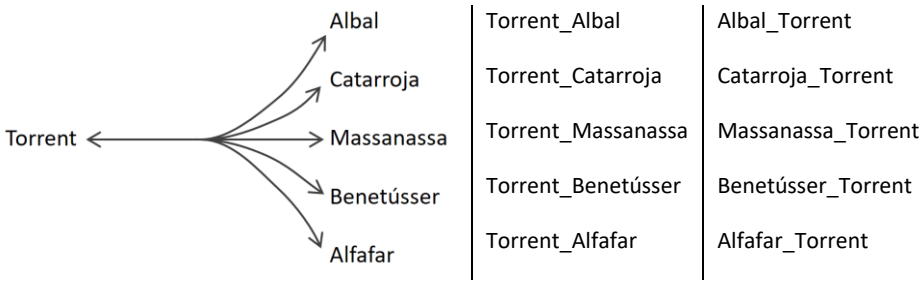


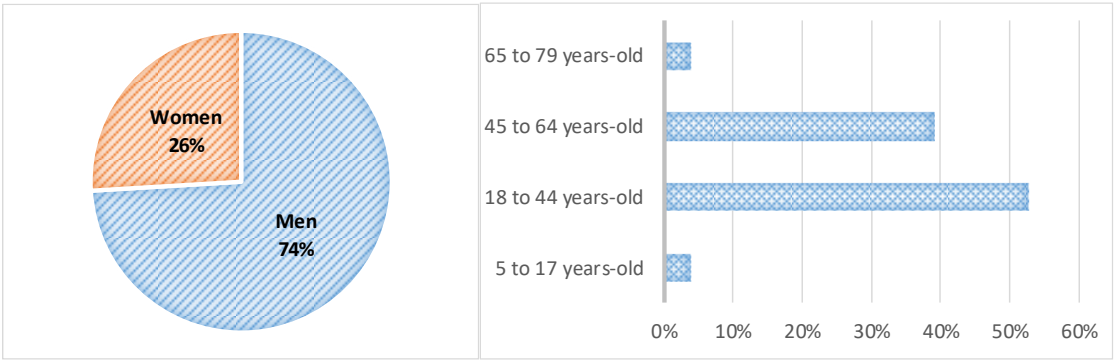
Figure 32. Set of possible origins and destinations at Solution 2.
Source: Own elaboration.

The route should give service to the industrial estates of Massanassa and "El Bony", as well as to the commercial area and the university and educational centre of La Florida (see Figure 30 above). Municipalities should also be connected by the suburban bus line in order to attract the maximum demand of passengers.

7.2.2. Analysis of the trips at the area of study

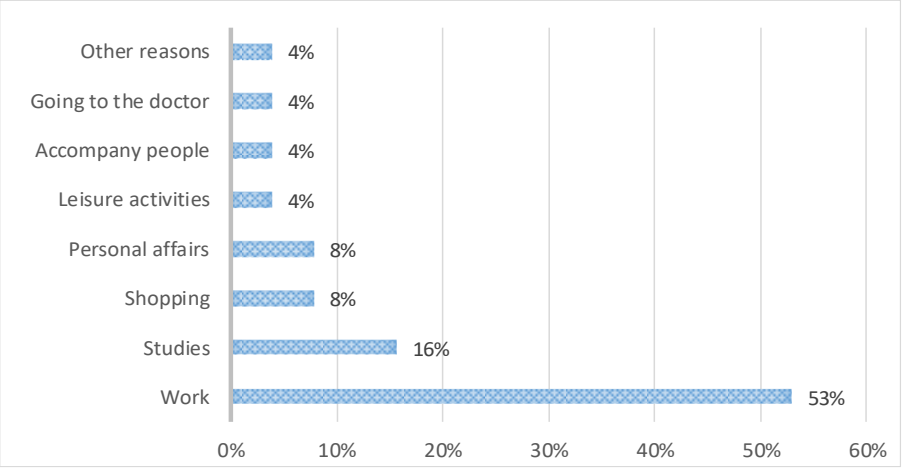
According to the computed data for this solution, the total number of displacements per day is 4.759 for this option. As there is no public transport service, every trip is made by private vehicle.

There is an unbalance between the number of women and men that travel: 74% of passengers are men and only 26% are women. The range of age that does the larger percentage of trips (53%) are those passengers between 18 and 44 years-old, followed by passengers between 45 and 64 years-old (39%).



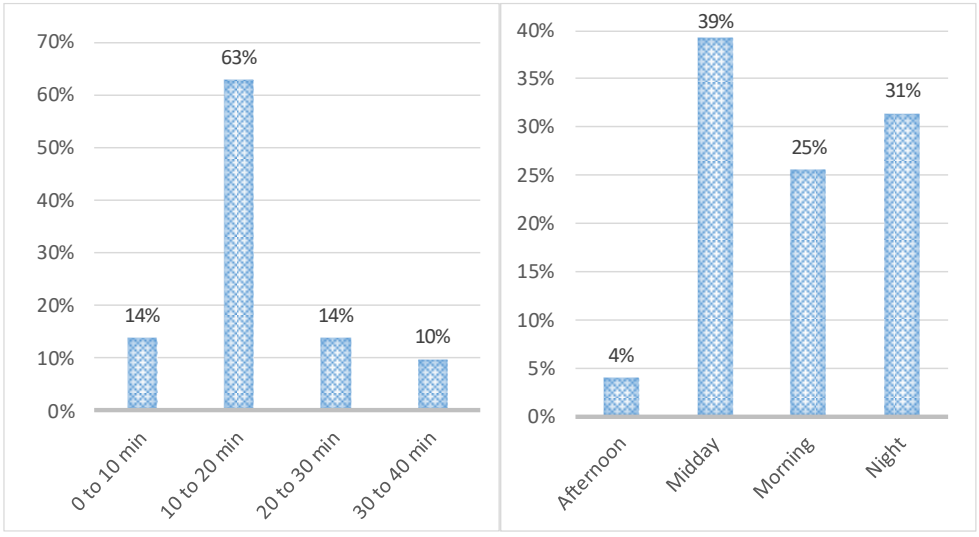
Graph 21. Gender and age distribution of private vehicle users (Solution 2).
Source: Own elaboration.

Going to work (53%) and studies (16%), followed by shopping and personal affairs (8%) are the two most relevant reasons for making a trip. Again, this is coherent with the age distribution represented: industrial estates areas attract the adult population and the university and educational centre captivates a younger sector of the population.



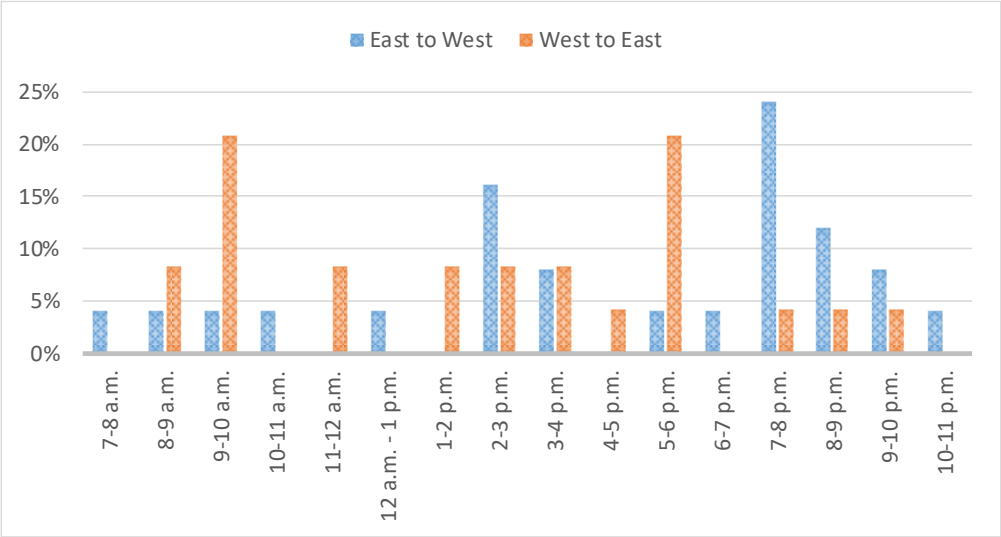
Graph 22. Reasons for making a trip at the area of study (Solution 2).
Source: Own elaboration.

Regarding the duration of displacements, the average is 18,37 minutes. The distribution of trips depending on the time of day is quite compensated between the morning (1.866 trips), midday (1.213 trips) and afternoon (1.493 trips).



Graph 23. Distribution of durations of trips (left) and number of trips depending on the time slot (right).
Source: Own elaboration.

A more detailed analysis of the distribution of trips along the day is shown in Graph 24.



Graph 24. Distribution of trips per hours (Solution 2).
Source: Own elaboration.

As it happened in Solution 1, there is a peak of displacements in the morning and at the beginning of the afternoon (between 5:00 p.m. and 6:00 p.m.) going from Torrent to the industrial and commercial areas, which may be due to employees going working and people going shopping to the commercial centre. Trips in this direction get reduced as the day progresses.

In the opposite direction, there are few trips in the morning. At midday, when the morning shift has come to an end, the number of passengers increases. The greatest peak of displacements happens between 7:00 p.m. and 8:00 p.m., when industries close. Between 8:00 and 11:00 p.m. there still some trips being done.

The following are the reasons of passengers for not using the public transport:

REASONS AGAINST THE USE OF THE PUBLIC TRANSPORT	
There is no public transport service or it is inappropriate	70%
It is not comfortable	7%
Price	7%
Low frequency	4%
Inappropriate schedules	4%
Too slow	4%
Other reasons	4%

Table 18. Reasons for not using public transportation. Source: Own elaboration.

The main reason that passengers give for not using the public transport is that there is no service or that it is inappropriate (70%), followed by the fact that it is not comfortable (7%) and that it is expensive (7%). The result is in line what was expected: the lack of public transport service at the zone leaves no other option rather than using the private vehicle.

7.2.3. Metrobús new service proposal on the map

This second solution has also been drawn following the requirements that had been exposed for the first option. That is, the line should properly link municipalities and working and leisure centres, trying to cross them by their principal streets, and should also offer appropriate safe areas for the bus to stop.

This time, we have come up with the solution illustrated in Figure 33. The itinerary is again circular with a total of 10 stops (blue dots at the figure): Torrent, Florida, Catarroja-South, IE El Bony, Catarroja-North, Massanassa, IKEA, MN4, Alfafar and Benetússer. The itinerary would be the same as the one in the first solution until arriving to Benetússer, but in this second option the bus would take the road CV-400 for going back to Torrent, shortening the itinerary.

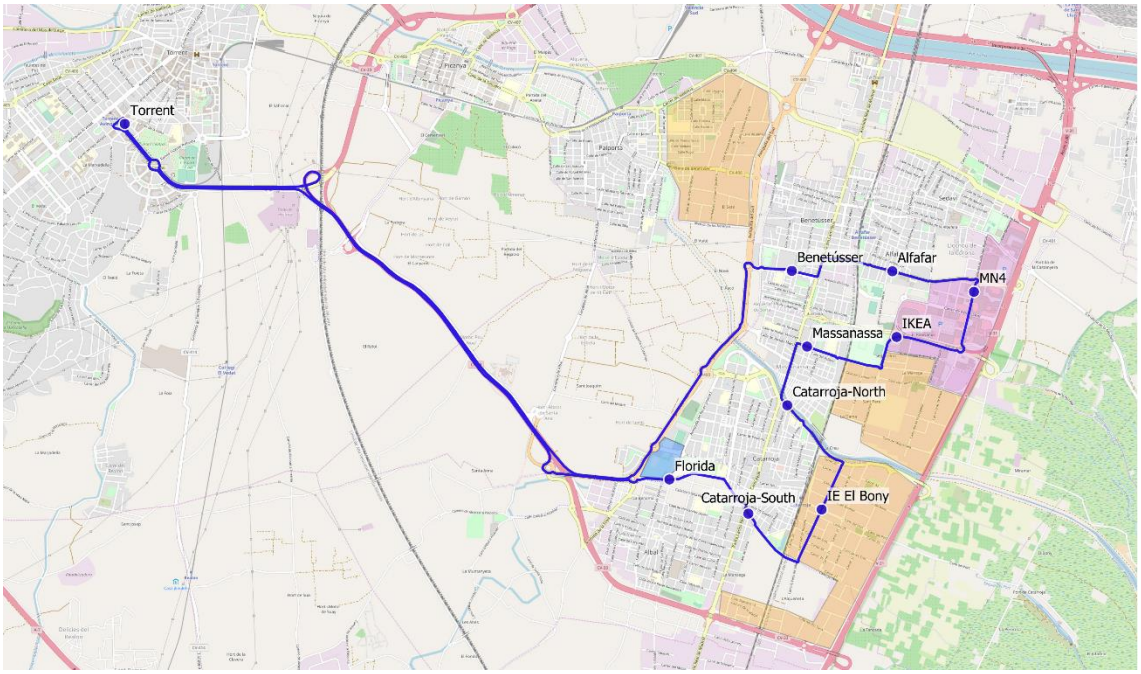


Figure 33. Proposal of Metrobús line (Solution 2).
Source: Own elaboration.

7.2.4. Application of the Logit model

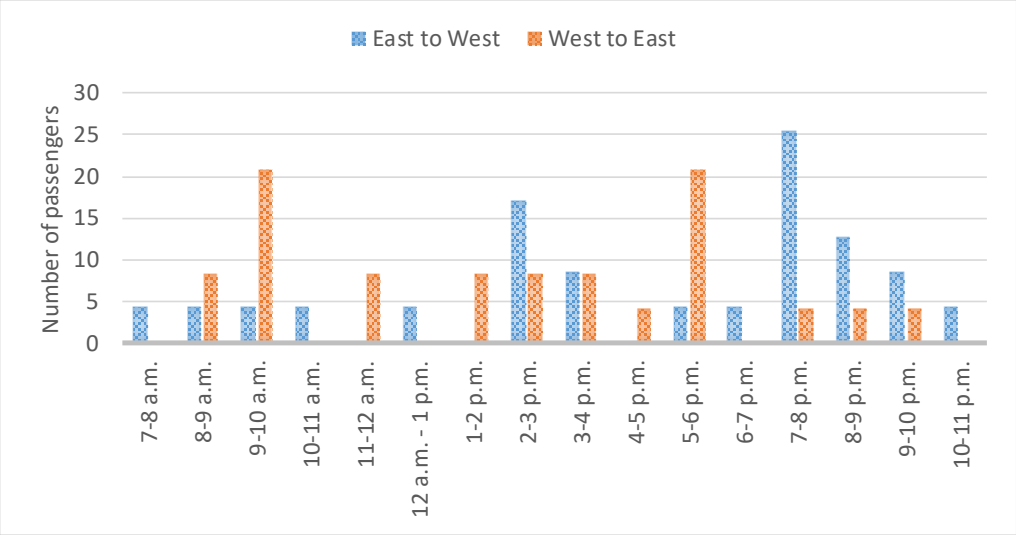
Costs associated to the use of the private vehicle according to the duration of the trip have been again calculated considering a cost of the fuel of 1,169 €/litre, a mean consumption of 6 litres of carburant per 100 kilometres and an average speed of 65 kilometres per hour.

The cost of the ticket of Metrobús, as explained in section 7.1.4, has been fixed in 1,55 euro per trip.

Using the same method described in section 7.1.4, the average probability of using Metrobús has been calculated; it is obtained a 4,32%. This means that, if the total number of trips that are made at the route under study is 4.759, the average number of trips that would be made by Metrobús is the 4,32% of this amount, that is, 206 trips per day.

7.2.5. Timetable of the new line

According to the trip distribution per hour shown in Graph 24, the number of estimated Metrobús trips per hours along the day is obtained, with the following representation:



Graph 25. Distribution of potential Metrobús trips per hours along the day.
Source: Own elaboration.

The greatest demand peak happens in the afternoon, with 25 potential Metrobús users going from Torrent to the commercial and industrial zone; in the morning 21 passengers would go from Torrent to such zone, and in the early afternoon 21 passengers would travel in the opposite direction.

The following schedule is proposed for the new suburban bus line:

Torrent	La Florida	Catarroja-South	IE "El Bony"	Catarroja-North	Massanassa	IKEA	MN4	Alfafar	Benetússer	Torrent
7:45	7:53	7:56	7:59	8:03	8:06	8:10	8:14	8:17	8:22	8:33
8:09	8:17	8:20	8:23	8:27	8:30	8:34	8:38	8:41	8:46	8:57
8:33	8:41	8:44	8:47	8:51	8:54	8:58	9:02	9:05	9:10	9:21
8:57	9:05	9:08	9:11	9:15	9:18	9:22	9:26	9:29	9:34	9:45
11:00	11:08	11:11	11:14	11:18	11:21	11:25	11:29	11:32	11:37	11:48
13:45	13:53	13:56	13:59	14:03	14:06	14:10	14:14	14:17	14:22	14:33
14:09	14:17	14:20	14:23	14:27	14:30	14:34	14:38	14:41	14:46	14:57
14:33	14:41	14:44	14:47	14:51	14:54	14:58	15:02	15:05	15:10	15:21
14:57	15:05	15:08	15:11	15:15	15:18	15:22	15:26	15:29	15:34	15:45
17:30	17:38	17:41	17:44	17:48	17:51	17:55	17:59	18:02	18:07	18:18
18:30	18:38	18:41	18:44	18:48	18:51	18:55	18:59	19:02	19:07	19:18
18:54	19:02	19:05	19:08	19:12	19:15	19:19	19:23	19:26	19:31	19:42
19:18	19:26	19:29	19:32	19:36	19:39	19:43	19:47	19:50	19:55	20:06
19:42	19:50	19:53	19:56	20:00	20:03	20:07	20:11	20:14	20:19	20:30
20:06	20:14	20:17	20:20	20:24	20:27	20:31	20:35	20:38	20:43	20:54

Table 19. Metrobús schedule for Solution 2.
Source: Own elaboration.

The travel time for doing a whole round of 25,0 kilometres is 48 minutes, so it would be necessary to have two buses, as the frequency is up to 24 minutes during peak hours. The total number of rounds that would be made per day is 15. The service would be given seven days a week.

7.2.6. Economic analysis of the proposal

This second option runs along 25,0 kilometres. There would be driven 15 rounds per day, so the total number of kilometres per day would be 375. The number of kilometres travelled per year would be 136.875. Taking into account that there would be two buses available, each of them would travel 65.625 kilometres per year.

Each round takes 48 minutes to be completed. Considering resting periods and a margin for taking the bus to the first station of the line and for going back to the parking lot in the afternoon, the total number of hours worked per day by the set of all employees is 28. Then, in a year, the total number of hours worked would be 10.220 (5.110 per bus).

The maximum number of hours that an employee can do per year is 1.768 hours. In consequence, we will need a total of 510.220 /1.768 ≈ 6 employees for making the service possible.

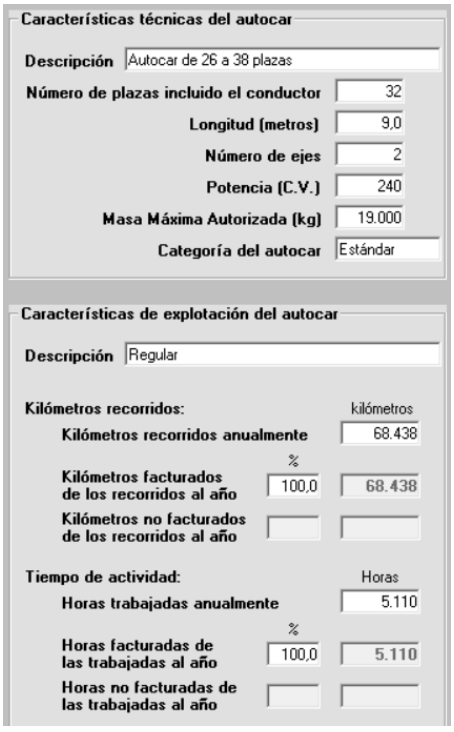
In section 7.1.6 it has been calculated the minimum salary and bonuses in 2019, which are 21.885,75 and 1.882,00 euro, respectively. Needing 6 drivers, the total personal costs will be 131.314,5 euro in terms of salary (65.657,25 euro per bus) and 11.292 euro in terms of bonus (5.646 euro per bus).

It is possible to use the same bus type used for Solution 1 but with less number of seats in order to augment the commodity of passengers by widening the interspace. The cost of the bus does not vary from the former solution.

Results of ACOTRAVI are the following in this case:

1) **Technical and operational characteristics**, which contains the following information:

- Number of seats: 32
- Length (metres): 9
- Number of axles: 2
- Horsepower (C.V.): 240
- Maximum Authorized Mass (kg): 19.000
- Category of the bus: Regular
- Kilometres travelled per year: 68.438
- Billed kilometres per year: 100%; 68.438
- Hours worked per year: 5.110
- Billed hours per year: 100%; 5.110

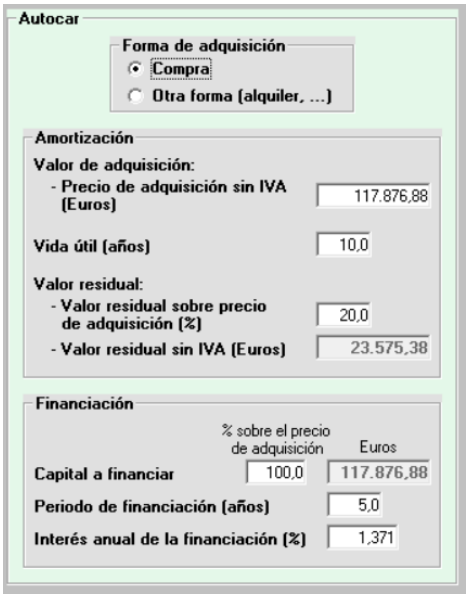


2) Amortization and financing

a) Form of acquisition: purchase

b) Amortization:
- Acquisition value without tax (€): 117.876,88
- Lifespan (years): 10
- Residual value on acquisition price (%): 20
- Residual value without tax (€): 23.575,38

c) Financing:
- Capital to be financed: 100%; 117.876,88 €
- Financing period (years): 5
- Annual interest (%): 1,371

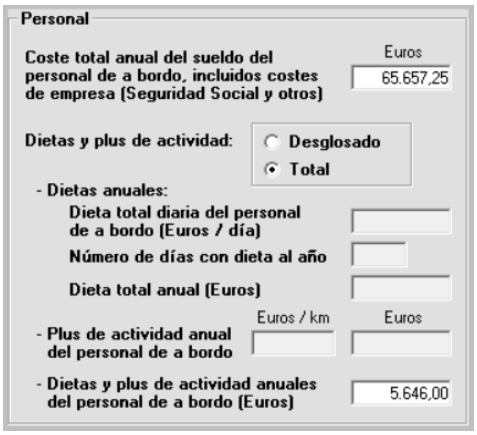


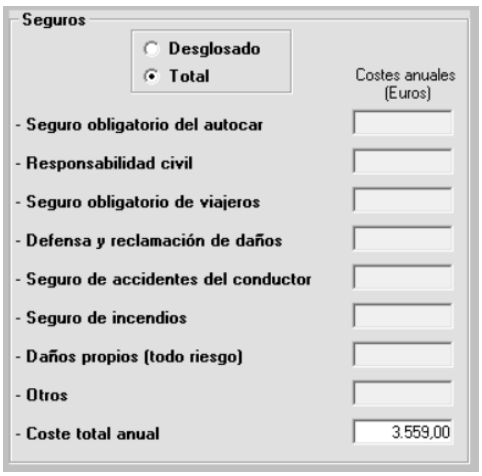
3) Personnel, insurance and fiscal costs

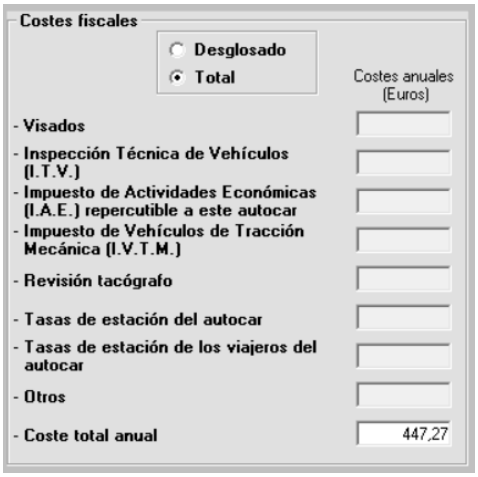
a) Personnel
- Annual salary (€): 65.657,25
- Annual bonus (€): 5.646,00

b) Insurance
- Total cost (€): 3.559,00

c) Fiscal costs
- Total cost (€): 447,27







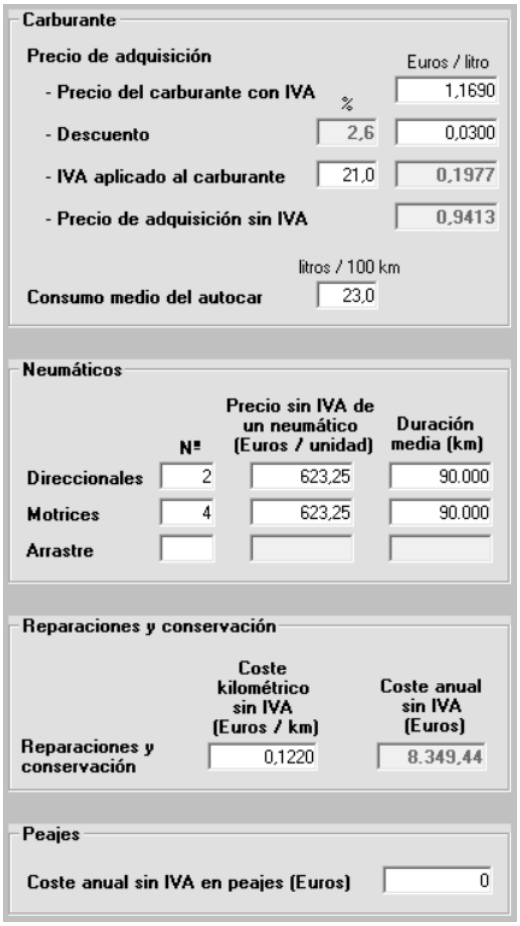
4) Variable costs

a) Fuel
- Cost with tax (€/l): 1,169
- Discount: 2,6%; 0,03 €/l
- Tax: 21%; 0,1977 €
- Final cost with tax (€/l): 0,9413
- Average consumption (l/100 km): 23

b) Tyres
- Directional tyres: 2 units; 623,25 €/unit; duration: 90.000 km
- Axle tyres: 4 units; 623,25 €/unit; duration: 90.000 km

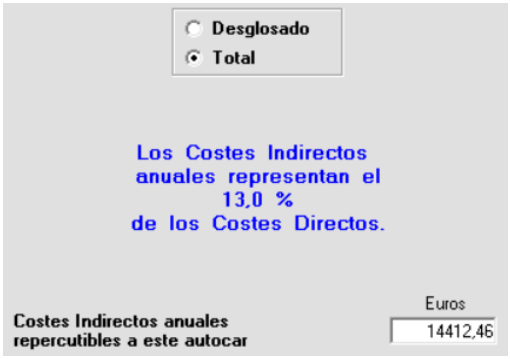
c) Repairs
- Total: 0,1220 €/km; 8.349,44 €/year

d) Tolls
- Total: 0 €



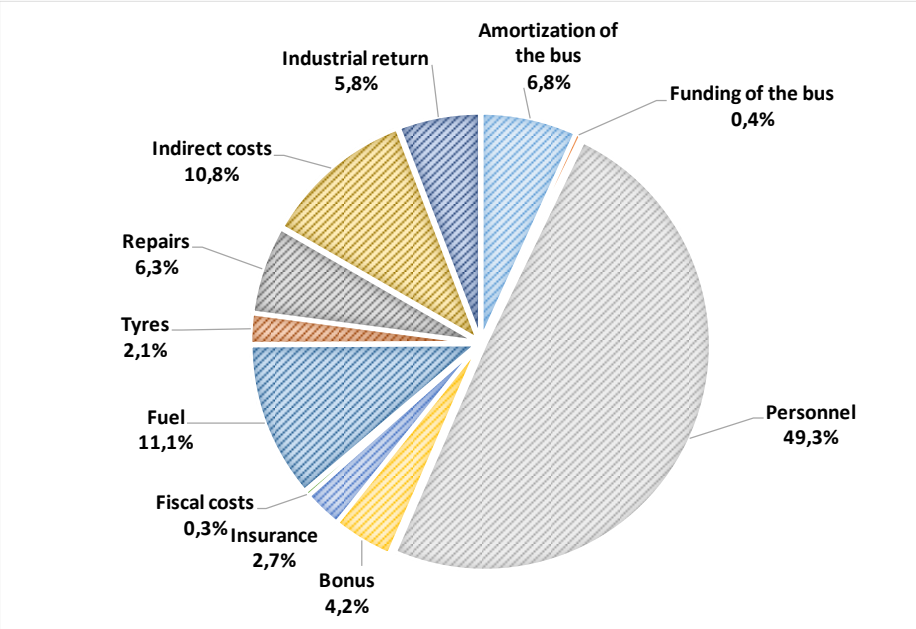
5) Indirect costs

a) Indirect costs = 13,0% of direct costs: 14.412,46 €.



6) Results

ANNUAL COSTS	Euro (€)	%
Total costs chargeable to all services	**120.859,10**	**100,0**
Direct costs	**110.865,10**	**83,3**
- Temporary costs	**84.854,95**	**63,8**
Amortization of the bus	9.056,20	6,8
Funding of the bus	489,23	0,4
Personnel	65.657,25	49,4
Bonus	5.646,00	4,2
Insurance	3.599,00	2,7
Fiscal costs	447,27	0,3
- Kilometric costs	**26.010,15**	**19,6**
Fuel	14.817,11	11,1
Tyres	2.843,60	2,1
Repairs	8.349,44	6,3
Tolls	0,00	0,0
Indirect costs (13% of direct costs)	**14.412,46**	**10,8**
Industrial return (7% of direct costs)	**7.760,56**	**5,8**



Graph 26. Costs distribution for Solution 2.
Source: Own elaboration based on the results obtained at ACOTRAVI.

The total cost of one bus per year is 133.038,12 euro. For implementing this second proposal it is necessary to use two buses, so the total cost per year would be 266.076,23 euro.

The potential demand that has been calculated in section 7.2.4 is 206 passengers for a 1,55-euro ticket. The total number of passengers per year is 75.190. The annual income is obtained by multiplying the number of passengers per year and the cost of a ticket, 1,55 x 75.190 = 116.544,5 euro.

Then, the annual balance result of the service would be 116.544,5 - 266.076,23 = -149.531,73 euro (56% of total costs). For implementing the service, the local government should economically contribute with this quantity so the transport company would not incur in losses. The percentage of the costs that local authorities should contribute with is higher than the average (30% of total costs), so we consider that the result obtained with this solution is not optimal enough.

The price of the ticket for not having losses would be 3,54 euro.

7.3. Comparison between Solution 1 and Solution 2

We can see in Figure 34 both solutions superposed in the map. The first one, in black, is circular and longer than the second one, in orange. Thus, Solution 1 absorbs a larger demand than Solution 2.

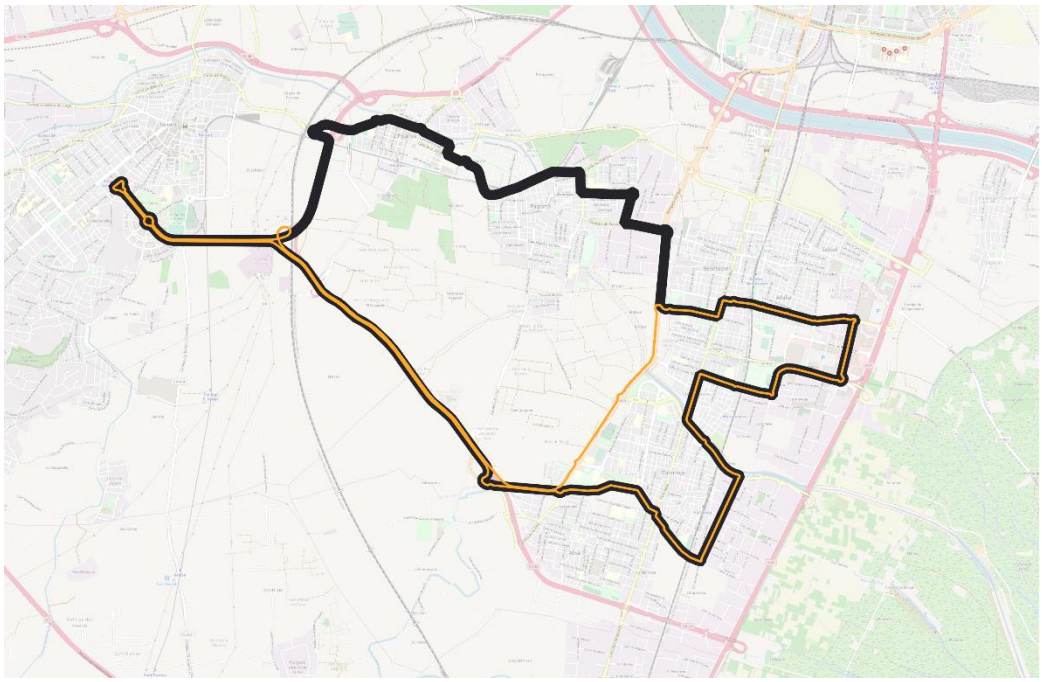


Figure 34. Solution 1 and Solution 2 on the map.
Source: Own elaboration.

The cost of the ticket for having positive economic results in Solution 2 (3,54€) is much higher than the cost of the ticket with Solution 1 (1,81 €). This is due to the fact that the first alternative travels through more locations while the travelled distance is almost the same: the first option runs 25,3 kilometres and the second one 25 kilometres. However, only by travelling 300 more metres, the demand is doubled, as the set of possible origins and destinations is multiplied: there are 206 potential passengers with Solution 2 while there exist 422 potential users with Solution 1.

Table 20 contains a summary of the cost of two buses for each alternative. It can be seen that the total cost of both options is very similar. However, the number of passengers that contribute to pay for the service in the first solution is higher; this leads to very different prices for the ticket between the two alternatives for arriving to the break-even point. Furthermore, if the price of the ticket in the second alternative was set in 3,54 € (price of the ticket for which the company would not incur losses), the difference between the cost of the trip made by the private vehicle and the cost of the trip made by Metrobús would be higher and thus, the probability of people using Metrobús would be reduced. This would make the demand even scarcer and would lead to the augmentation of the cost of the ticket.

ANNUAL COSTS (€)	**Solution 1**	**Solution 2**
Total costs chargeable to all services	**279.459,00**	**266.076,23**
Direct costs	**232.882,50**	**221.730,20**
- Temporary costs	**169.709,90**	**169.709,90**
Amortization of the bus	18.112,40	18.112,40
Funding of the bus	978,46	978,46
Personnel	131.314,50	131.314,50
Bonus	11.292,00	11.292,00
Insurance	7.118,00	7.198,00
Fiscal costs	894,54	894,54
- Kilometric costs	**63.172,60**	**52.020,30**
Fuel	35.987,32	29.634,22
Tyres	6.906,44	5.687,20
Repairs	20.278,84	16.698,88
Tolls	0,00	0,00
Indirect costs	**30.274,72**	**28.824,92**
Industrial return	**16.301,78**	**15.521,11**

Table 20. Comparison between the costs of the two solutions.
Source: Own elaboration based on the results obtained at ACOTRAVI.

The following table resumes the annual income/revenue of the service, the total costs of the service and the economic contribution that the local government should make for covering the deficit which will provide null operation results (that is, for not having losses).

	Solution 1	Solution 2
Revenue of the service (€)	238.746,50	116.544,50
Contribution due to deficit (€)	40.712,50	149.531,73
Total costs of the service (€)	279.459,00	266.076,23
Operation results (€)	0,00	0,00

Table 21. Operation results of the two solutions.
Source: Own elaboration based on the results obtained at ACOTRAVI.

Concluding, the first solution has a smaller deficit (14,5%) that local authorities could cover for the benefit of the valencian society, so this solution would be the one to implement.

7.4. Future developments for an optimal Transport Policy

Along this work, we have essentially sustained an economic (cost based) perspective in our proposals. This focus is appropriate from the point of view of the passenger, as the model is based on the difference between private vehicle and suburban bus costs for the individual; and is also adequate for the transport company, as the implementation of the new bus line is a result of a potential demand analysis with the aim of having positive economic results.

However, the creation of a new public transport service should also consider other aspects such as regional planning policies, urban expansion or environmentally sustainable issues. For this reason, we think that future developments of this work should take into account these considerations. Perhaps, this could be made through the study of the variables that had no especial economic significance (in terms of cost-benefit analysis) in the Logit model. These variables were:

- GENDER: in spite of the fact that our analysis included some distinctions between percentage of women and men moving at the area of study, nowadays gender studies are more and more appreciated. Thus, this would be an *avant-garde* research line.
- AFTERN (trips made between 5:00 p.m. and 10 p.m.): it would be interesting to find out if levels of pollution at the Metropolitan Region of Valencia vary according to the time slot[22].

[22] According to data provided by the Valencian Ministry of Housing, Public Works and Territorial Planning (Conselleria d'Habitatge, Obres Públiques i Vertebració del Territori), the levels of pollution recorded at the area of study present peaks at 7:00 a.m. and 7:00 p.m. aprox.

In such case, it would be useful to substitute the conventional combustion engine buses for hybrid or electric ones (as the EMT-Valencia is already doing).

- STUDENT and LOOKING (for a job): the use of Metrobús could be incentivized by having special fares for these groups of population. Furthermore, university and educational centres could directly inform students about this service and its advantages.
- As the different variables regarding the level of studies of passengers did not show that people with studies acted differently to those without studies, a global marketing campaign addressed to the whole population could be made for promoting the use of the suburban bus.

8. Conclusions

We began this study explaining that the growth of the population over the past decades has led to an overcrowding of the urban nucleus of city of Valencia and to the expansion of the limits of the capital. While the main city is no longer the immediate option in which to get established and live, proximate municipalities gain population. However, the public transport network does not expand at the same rate that the urban area does: connections are stills scarce between metropolitan municipalities and the use of the private vehicle is often necessary. Some steps towards the improvement of mobility have been taken by local authorities, such as the publication of the Mobility Plan for the Urban Area of Valencia (PMUS) in 2013 or the Basic Mobility Plan for the Metropolitan Area of Valencia (PMoME) in 2018, which deals with the territorial and mobility model for building a sustainable society. The objective of this work is to give continuity to these plans by developing a statistical tool which could be used for estimating the demand of new public transport services.

For doing so, an analysis of the public transport supply and demand has been made in order to have a global vision of the situation of Valencia. It has been seen that the public transport network runs through radial corridors starting from the main city that are not linked; thus, municipalities located at different corridors are left with almost no connections between them. We have come to the conclusion that nowadays, against the alternative offered by the massive use of private vehicles, the best option for solving the mobility problem would lay on the implementation of new suburban bus lines linking nucleuses with substantial mobility flows.

Consequently, we have continued focusing our attention on the analysis of routes with no public transport connections other than the suburban bus (Metrobús), with the aim of understanding how the different characteristics of population and how the nature of trips being made at these itineraries have an influence in the decision of choosing one transport mode or the other (in our case, the private vehicle vs Metrobús). For transforming these observed attributes (gender, age, professional activity, level of studies, day of the week, cost and duration of the trip, etc.) into a statistical expression, a discrete choice Logit model has been developed using Mplus (a

modelling program) in order to obtain the probability for a person of choosing to travel by Metrobús. As our goal is to build a tool that a transport company could use to make technical decisions for implementing new bus lines, we have sustained a cost based perspective, so our model will finally depend on the difference between the costs of a certain trip made by the private vehicle and the cost of this same displacement made by the suburban bus.

We have followed with the identification of an area of study in which to apply the results of our model for the further proposal of a new Metrobús line. The northern zone of the Metropolitan Region of Valencia has a denser public transport network, and at the southern zone there are two clearly unconnected axes: one containing Torrent, Picanya and Paiporta (West axe) and other passing through Albal, Catarroja, Massanassa, Alfafar and Benetússer (East axe); it is here where we have decided to set up a new suburban bus line. Two proposals have been studied: a longer, more time consuming and costlier to create but higher in demand alternative, and a shorter, less time consuming but lower in demand option. Applying the probability function obtained after the estimation of the Logit model, we have calculated the potential demand of each new line and we have made an economic analysis of both proposals. The first solution provides better economic results, so this is the alternative that has been chosen to be implemented at the region for linking the two axes.

Finally, we have sketched some possible future developments of this work taking into account regional planning policies, urban expansion or environmentally sustainable considerations. The urban expansion and the public transport network development should come hand by hand for reaching a sustainable society model: if one of them gets boosted without the other one accompanying this growth, the model would be out of balance. In addition, the climate change forces to take global and local measures for reducing the levels of pollution, and being the transport industry one of the most polluting sectors in the world, it is a must to take specific actions to address the problem. The reinforcement of the public transport network of a city is vital for better quality of the air (which is also essential for avoiding health problems associated to air pollution). It is essential to raise the visibility of this issue and to demonstrate that a social and economic profitable change is possible.

Conclusions

Nous avons commencé cette étude en expliquant que la croissance de la population au cours des dernières décennies a conduit à un surpeuplement du noyau urbain de la ville de Valence et à l'expansion des limites de la capitale. Alors que la ville principale n'est plus l'option immédiate pour s'établir et vivre, les municipalités périphériques gagnent en population. Cependant, le réseau de transport public ne se développe pas au même rythme : les liaisons entre les municipalités métropolitaines sont encore rares et l'utilisation du véhicule privé est souvent nécessaire. Certaines mesures visant à améliorer la mobilité ont été prises par les autorités locales, telles que la publication du Plan de Mobilité pour l'Agglomération de Valence (PMUS)

en 2013 ou le Plan de Mobilité pour la Région Métropolitaine de Valence (PMoME) en 2018, qui traite du modèle territorial et de mobilité pour construire une société durable. L'objectif de ce travail est d'assurer la continuité de ces plans en développant un outil statistique qui pourrait être utilisé pour estimer la demande de nouveaux services de transport public.

Pour ce faire, une analyse de l'offre et de la demande de transports publics a été réalisée afin d'avoir une vision globale de la situation à Valence. On a vu que le réseau de transport public passe par des couloirs radiaux à partir du centre de la ville qui ne sont pas reliés ; ainsi, les municipalités situées dans des couloirs différents se retrouvent avec presque pas des liens entre eux. Nous sommes arrivés à la conclusion qu'aujourd'hui, face à l'alternative offerte par l'utilisation massive des véhicules privés, la meilleure option pour résoudre le problème de la mobilité consisterait à mettre en place de nouvelles lignes de bus suburbaines reliant les noyaux à des flux de mobilité importants.

Par conséquent, nous avons continué avec l'analyse des itinéraires sans offre de transport public autres que le bus suburbain (Metrobús), dans le but de comprendre comment les différentes caractéristiques de la population et comment la nature des déplacements effectués sur ces itinéraires ont une influence dans la décision de choisir un mode de transport ou l'autre (dans notre cas, le véhicule privé ou Metrobús). Pour transformer ces attributs observés (sexe, âge, activité professionnelle, niveau d'études, jour de la semaine, coût et durée du voyage, etc.) en une expression statistique, un modèle Logit à choix discret a été développé en utilisant Mplus (un programme de modélisation) afin d'obtenir la probabilité pour une personne de choisir de voyager avec Metrobús. Comme notre objectif est de construire un outil qu'une entreprise de transport pourrait utiliser pour prendre des décisions techniques pour l'implantation de nouvelles lignes d'autobus, nous avons maintenu une perspective basée sur les coûts, de sorte que notre modèle dépendra finalement de la différence entre les coûts d'un certain trajet effectué par le véhicule privé et les coûts de ce même déplacement effectué par l'autobus suburbain.

Nous avons ensuite identifié un domaine d'étude dans lequel appliquer les résultats de notre modèle pour la proposition d'une nouvelle ligne Metrobús. La zone nord de la région métropolitaine de Valence dispose d'un réseau de transports publics plus dense et, dans la zone sud, il existe deux axes clairement non reliés : l'un contenant Torrent, Picanya et Paiporta (Axe Ouest) et l'autre passant par Albal, Catarroja, Massanassa, Alfafar et Benetússer (Axe Est), où nous avons décidé de créer une nouvelle ligne de bus suburbain. Deux propositions ont été étudiées : une alternative plus longue et plus coûteuse à créer, mais avec plus de demande, et une option plus courte, moins longue mais avec moins demande. En appliquant la fonction de probabilité obtenue après l'estimation du modèle Logit, nous avons calculé la demande potentielle de chaque nouvelle ligne et nous avons fait une analyse économique des deux propositions. La première solution donne de meilleurs résultats économiques, c'est donc l'alternative qui a été choisie pour être mise en œuvre dans la région pour relier les deux axes.

Enfin, nous avons esquissé certains développements futurs possibles de ces travaux en tenant compte des politiques d'aménagement du territoire, de l'expansion urbaine ou de considérations environnementales durables. L'expansion urbaine et le développement du réseau de transport public doivent aller de pair pour parvenir à un modèle de société durable : si l'un d'entre eux est dynamisé sans que l'autre accompagne cette croissance, le modèle serait déséquilibré. En outre, le changement climatique oblige à prendre des mesures mondiales et locales pour réduire les niveaux de pollution, et étant donné que l'industrie des transports est l'un des secteurs les plus polluants au monde, il est indispensable de prendre des mesures spécifiques pour résoudre le problème. Le renforcement du réseau de transport public d'une ville est vital pour une meilleure qualité de l'air (ce qui est également essentiel pour éviter les problèmes de santé liés à la pollution atmosphérique). Il est essentiel d'accroître la visibilité de cette question et de démontrer qu'un changement social et économiquement viable est possible.

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10. Appendices

10.1. Appendix 1. Transport zones defined at the PMoME

Table 22. Transport zones. Source: PMoME.

Transport zone	Municipality	Transport zone	Municipality	Transport zone	Municipality	Transport zone	Municipality
1	València	**140**	València	**279**	Sueca	**418**	Paterna
2	València	**141**	València	**280**	Sueca	**419**	Paterna
3	València	**142**	València	**281**	Sueca	**420**	Paterna
4	València	**143**	València	**282**	Sueca	**421**	Paterna
5	València	**144**	València	**283**	Alboraya	**422**	Paterna
6	València	**145**	València	**284**	Alboraya	**423**	Paterna
7	València	**146**	València	**285**	Alboraya	**424**	Paterna
8	València	**147**	València	**286**	Alboraya	**425**	Paterna
9	València	**148**	València	**287**	Alboraya	**426**	Paterna
10	València	**149**	València	**288**	Alboraya	**427**	Paterna
11	València	**150**	València	**289**	Alboraya	**428**	Paterna
12	València	**151**	València	**290**	Alboraya	**429**	Paterna
13	València	**152**	València	**291**	Alboraya	**430**	Paterna
14	València	**153**	València	**292**	Tavernes B.	**431**	Paterna
15	València	**154**	Xirivella	**293**	Tavernes B.	**432**	Burjassot
16	València	**155**	Xirivella	**294**	Almàssera	**433**	Burjassot
17	València	**156**	València	**295**	Almàssera	**434**	Burjassot
18	València	**157**	València	**296**	Bonrepòs i M.	**435**	Burjassot
19	València	**158**	València	**297**	Meliana	**436**	Burjassot
20	València	**159**	València	**298**	Meliana	**437**	Burjassot
21	València	**160**	València	**299**	Meliana	**438**	Burjassot
22	València	**161**	València	**300**	Foios	**439**	Burjassot
23	València	**162**	València	**301**	Foios	**440**	Burjassot
24	València	**163**	València	**302**	Foios	**441**	Godella
25	València	**164**	València	**303**	Vinalesa	**442**	Godella
26	València	**165**	València	**304**	Albalat dels S.	**443**	Godella
27	València	**166**	València	**305**	Albalat dels S.	**444**	Godella
28	València	**167**	València	**306**	Albalat dels S.	**445**	Cheste
29	València	**168**	València	**307**	Albuixech	**446**	Cheste
30	València	**169**	València	**308**	Albuixech	**447**	Cheste
31	València	**170**	València	**309**	Emperador	**448**	Cheste
32	València	**171**	València	**310**	Museros	**449**	Cheste
33	València	**172**	València	**311**	Museros	**450**	Cheste
34	València	**173**	València	**312**	Museros	**451**	Chiva
35	València	**174**	València	**313**	Massalfassar	**452**	Chiva
36	València	**175**	València	**314**	Massalfassar	**453**	Chiva
37	València	**176**	València	**315**	Massalfassar	**454**	Chiva
38	València	**177**	València	**316**	Massamagrell	**455**	Chiva
39	València	**178**	València	**317**	Massamagrell	**456**	Chiva
40	València	**179**	València	**318**	Massamagrell	**457**	Godelleta
41	València	**180**	València	**319**	Massamagrell	**458**	Godelleta
42	València	**181**	València	**320**	Pobla Farnals	**459**	Montserrat
43	València	**182**	València	**321**	Pobla Farnals	**460**	Montserrat
44	València	**183**	València	**322**	Pobla Farnals	**461**	Montserrat
45	València	**184**	València	**323**	Rafelbunyol	**462**	Turís
46	València	**185**	València	**324**	Rafelbunyol	**463**	Turís

47	València	**186**	València	**325**	Puig de S.M.	**464**	Turís
48	València	**187**	Xirivella	**326**	Puig de S.M.	**465**	Turís
49	València	**188**	Xirivella	**327**	Puig de S.M.	**466**	Turís
50	València	**189**	Xirivella	**328**	Puig de S.M.	**467**	Turís
51	València	**190**	Xirivella	**329**	Puig de S.M.	**468**	Mislata
52	València	**191**	Xirivella	**330**	Puçol	**469**	Mislata
53	València	**192**	Xirivella	**331**	Puçol	**470**	Mislata
54	València	**193**	Xirivella	**332**	Puçol	**471**	Mislata
55	València	**194**	Aldaia	**333**	Puçol	**472**	Mislata
56	València	**195**	Aldaia	**334**	Puçol	**473**	Mislata
57	València	**196**	Aldaia	**335**	Puçol	**474**	Mislata
58	València	**197**	Aldaia	**336**	Puçol	**475**	Mislata
59	València	**198**	Aldaia	**337**	Puçol	**476**	Mislata
60	València	**199**	Aldaia	**338**	Puçol	**477**	Quart de P.
61	València	**200**	Aldaia	**339**	Sagunto	**478**	Quart de P.
62	València	**201**	Aldaia	**340**	Sagunto	**479**	Quart de P.
63	València	**202**	Aldaia	**341**	Sagunto	**480**	Quart de P.
64	València	**203**	Aldaia	**342**	Sagunto	**481**	Quart de P.
65	València	**204**	Aldaia	**343**	Sagunto	**482**	Quart de P.
66	València	**205**	Aldaia	**344**	Sagunto	**483**	Quart de P.
67	València	**206**	Alaquàs	**345**	Sagunto	**484**	Quart de P.
68	València	**207**	Alaquàs	**346**	Sagunto	**485**	Quart de P.
69	València	**208**	Alaquàs	**347**	Sagunto	**486**	Quart de P.
70	València	**209**	Alaquàs	**348**	Sagunto	**487**	Quart de P.
71	València	**210**	Alaquàs	**349**	Sagunto	**488**	Quart de P.
72	València	**211**	Sedaví	**350**	Sagunto	**489**	Quart de P.
73	València	**212**	Sedaví	**351**	Sagunto	**490**	Quart de P.
74	València	**213**	Sedaví	**352**	Sagunto	**491**	Manises
75	València	**214**	Llocnou C.	**353**	Sagunto	**492**	Manises
76	València	**215**	Benetússer	**354**	Sagunto	**493**	Manises
77	València	**216**	Benetússer	**355**	Sagunto	**494**	Manises
78	València	**217**	Alfafar	**356**	Canet d'En B.	**495**	Manises
79	València	**218**	Alfafar	**357**	Canet d'En B.	**496**	Manises
80	València	**219**	Alfafar	**358**	Rocafort	**497**	Manises
81	València	**220**	Alfafar	**359**	Rocafort	**498**	Manises
82	València	**221**	Alfafar	**360**	Moncada	**499**	Manises
83	València	**222**	Massanassa	**361**	Moncada	**500**	Manises
84	València	**223**	Massanassa	**362**	Moncada	**501**	Manises
85	València	**224**	Massanassa	**363**	Moncada	**502**	Manises
86	València	**225**	Massanassa	**364**	Moncada	**503**	Riba-roja T.
87	València	**226**	Catarroja	**365**	Moncada	**504**	Riba-roja T.
88	València	**227**	Catarroja	**366**	Moncada	**505**	Riba-roja T.
89	València	**228**	Catarroja	**367**	Moncada	**506**	Riba-roja T.
90	València	**229**	Catarroja	**368**	Moncada	**507**	Riba-roja T.
91	València	**230**	Catarroja	**369**	Alfara Patr.	**508**	Riba-roja T.
92	València	**231**	Catarroja	**370**	Alfara Patr.	**509**	Riba-roja T.
93	València	**232**	Albal	**371**	Náquera	**510**	Riba-roja T.
94	València	**233**	Albal	**372**	Náquera	**511**	Riba-roja T.
95	València	**234**	Albal	**373**	Náquera	**512**	Riba-roja T.
96	València	**235**	Albal	**374**	Serra	**513**	Riba-roja T.
97	València	**236**	Albal	**375**	Serra	**514**	Vilamarxant
98	València	**237**	Albal	**376**	Eliana, l'	**515**	Vilamarxant
99	València	**238**	Beniparrell	**377**	Eliana, l'	**516**	Vilamarxant
100	València	**239**	Beniparrell	**378**	Eliana, l'	**517**	Vilamarxant

101	València	**240**	Beniparrell	**379**	Eliana, l'	**518**	Vilamarxant
102	València	**241**	Beniparrell	**380**	S.A. Benagéber	**519**	Loriguilla
103	València	**242**	Beniparrell	**381**	S.A. Benagéber	**520**	Loriguilla
104	València	**243**	Silla	**382**	S.A. Benagéber	**521**	Paiporta
105	València	**244**	Silla	**383**	P. Vallbona	**522**	Paiporta
106	València	**245**	Silla	**384**	P. Vallbona	**523**	Paiporta
107	València	**246**	Silla	**385**	P. Vallbona	**524**	Paiporta
108	València	**247**	Silla	**386**	P. Vallbona	**525**	Paiporta
109	València	**248**	Silla	**387**	P. Vallbona	**526**	Paiporta
110	València	**249**	Silla	**388**	P. Vallbona	**527**	Paiporta
111	València	**250**	Alcàsser	**389**	P. Vallbona	**528**	Picanya
112	València	**251**	Alcàsser	**390**	Bétera	**529**	Picanya
113	València	**252**	Alcàsser	**391**	Bétera	**530**	Picanya
114	València	**253**	Alcàsser	**392**	Bétera	**531**	Picanya
115	València	**254**	Picassent	**393**	Bétera	**532**	Picanya
116	València	**255**	Picassent	**394**	Bétera	**533**	Torrent
117	València	**256**	Picassent	**395**	Bétera	**534**	Torrent
118	València	**257**	Picassent	**396**	Benissanó	**535**	Torrent
119	València	**258**	Picassent	**397**	Benaguasil	**536**	Torrent
120	València	**259**	Picassent	**398**	Benaguasil	**537**	Torrent
121	València	**260**	Picassent	**399**	Benaguasil	**538**	Torrent
122	València	**261**	Benifaió	**400**	Benaguasil	**539**	Torrent
123	València	**262**	Benifaió	**401**	Benaguasil	**540**	Torrent
124	València	**263**	Benifaió	**402**	Llíria	**541**	Torrent
125	València	**264**	Benifaió	**403**	Llíria	**542**	Torrent
126	València	**265**	Almussafes	**404**	Llíria	**543**	Torrent
127	València	**266**	Almussafes	**405**	Llíria	**544**	Torrent
128	València	**267**	Almussafes	**406**	Llíria	**545**	Torrent
129	València	**268**	Alginet	**407**	Llíria	**546**	Torrent
130	València	**269**	Alginet	**408**	Llíria	**547**	Torrent
131	València	**270**	Alginet	**409**	Llíria	**548**	Torrent
132	València	**271**	Carlet	**410**	Domeño	**549**	Torrent
133	València	**272**	Carlet	**411**	Paterna	**550**	Torrent
134	València	**273**	Carlet	**412**	Paterna	**551**	Torrent
135	València	**274**	Sollana	**413**	Paterna	**552**	Torrent
136	València	**275**	Sollana	**414**	Paterna	**553**	Torrent
137	València	**276**	Sollana	**415**	Paterna	**554**	Torrent
138	València	**277**	Sueca	**416**	Paterna	**555**	Torrent
139	València	**278**	Sueca	**417**	Paterna		

10.2. Appendix 2. EMT Valencia line characteristics

Table 23. EMT Valencia line chracteristics. Source: 2016 Statistics Report.

Line	Length (km)	Comercial Speed	Travel time	No. Buses/day	Passengers
Day lines					94.589.725
1	19,319	13,25	1h27'	10	2.347.673
2	21,322	12,74	1h40'	15	4.553.540
3	14,889	13,18	1h08'	11	3.102.530
4	13,683	12,56	1h05'	9	2.424.809
5	4,495	11,75	23'	4	1.424.754
6	16,808	11,86	1h25'	12	2.716.059
7	8,923	11,03	49'	7	1.261.166
8	11,143	11,82	57'	8	1.577.410
9	20	12,31	00'	12	2.832.719
10	17,913	11,42	1h34'	13	2.966.343
11	14,215	11,12	1h17'	11	2.663.780
12	15,242	12,8	1h11'	8	1.119.006
13	11,335	11,16	1h01'	6	1.315.505
14	20,848	15,85	1h19'	7	1.160.777
15	28,301	19,62	1h27'	1	100.830
16	18,557	16,67	1h07'	9	2.054.315
18	14,14	14,41	59'	6	1.138.416
19	15,938	12,21	1h18'	11	3.165.119
20 (*)	24,832	13,49	1h50'	7	375.634
23 (*)	24,785	15,77	1h34'	3	123.314
25	51,328	28,45	1h48'	5	855.316
26	23,607	17,42	1h21'	5	620.292
27	11,438	12,78	54'	9	2.343.106
28	11,655	12,76	55'	9	2.306.156
29	18,286	13,78	1h20'	11	1.412.109
30	13,285	15,43	52'	4	752.711
31	15,231	12,43	1h14'	7	1.595.324
32	15,179	11,6	1h19'	9	2.492.224
35	10,22	11,03	56'	7	1.969.883
40	9,425	11,19	51'	6	1.199.618
41	12,861	13,93	55'	6	654.635
60	10,252	11,9	52'	8	2.202.136
62	18,271	14,94	1h13'	8	1.819.772
63	14,17	20,34	42'	4	318.548

64	17,28	13,29	1h18'	11	2.650.063
67	11,458	12,42	55'	6	1.193.831
70	17,365	12,22	1h25'	12	2.784.559
71	17,744	11,42	1h33'	14	3.277.616
72	8,327	11,03	45'	7	1.571.885
73	15,208	12,14	1h15'	9	1.657.845
79	8,52	13,03	39'	5	1.559.773
80	8,615	12,37	42'	4	1.170.626
81	9,705	11,09	53'	9	2.635.228
89	12,447	12,32	1h01'	13	5.280.370
90	12,229	12,2	1h00'	13	5.398.067
95	24,378	14,59	1h40'	12	2.938.499
99	26,7	15,3	1h45'	12	3.505.834
Night lines					821.499
N1	14,145	17,06	50'	1	91.189
N2	12,341	18,96	39'	1	52.960
N3	15,79	20,93	45'	1	54.763
N4	12,546	17,91	42'	1	42.379
N5	11,279	15,13	45'	1	39.714
N6	12,465	16,58	45'	1	89.636
N7	10,44	15,33	41'	1	32.056
N8	11,768	15,83	45'	1	79.636
N9	13,962	15,46	54'	1	51.705
N10	12,967	17,31	45'	1	46.941
N89	12,423	16,88	44'	1	116.995
N90	12,251	17,19	43'	1	115.159
CN - Correnit	13,396	17,83	45'	2	8.366

(*) These lines are only offered during summer time

10.3. Appendix 3. Database matrix used in Mplus

MODE	DAY	WOMAN	AGE	AGERANGE	SLOT	COSTVP	COSTMB	DIFCOST	DURVP	DURMB	NMEMBERS	NCARS	NMOTOS	ACTIVITY	STUDIES	NTRIPS
0	3	0	43	2	3	1,56	1,45	0,11	20	30	5	1	0	19	9	4
0	3	0	43	2	3	1,56	1,45	0,11	20	15	5	1	0	19	9	4
0	3	0	43	2	2	0,78	1,45	-0,67	10	30	5	1	0	19	9	4
0	3	0	43	2	1	0,78	1,45	-0,67	10	15	5	1	0	19	9	4
0	2	0	40	2	3	2,34	1,45	0,89	30	30	4	1	0	19	9	4
0	2	0	40	2	2	1,17	1,45	-0,28	15	30	4	1	0	19	9	4
0	2	0	40	2	1	0,78	1,45	-0,67	10	30	4	1	0	19	9	4
0	2	0	40	2	1	0,78	1,45	-0,67	10	30	4	1	0	19	9	4
0	2	1	39	2	3	2,34	2,7	-0,36	30	75	4	1	1	19	9	4
0	2	1	39	2	3	2,34	2,7	-0,36	30	75	4	1	1	19	9	4
0	2	1	39	2	1	1,17	2,7	-1,53	15	75	4	1	1	19	9	4
0	2	1	39	2	1	1,17	2,7	-1,53	15	75	4	1	1	19	9	4
0	2	0	56	3	3	0,78	1,45	-0,67	10	30	2	1	0	19	9	4
0	2	0	56	3	2	0,78	1,45	-0,67	10	30	2	1	0	19	9	4
0	2	0	56	3	2	0,39	1,45	-1,06	5	30	2	1	0	19	9	4
0	2	0	56	3	1	0,78	1,45	-0,67	10	30	2	1	0	19	9	4
0	2	1	55	3	3	1,56	1,45	0,11	20	30	2	2	1	19	9	2
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1	5	1	63	3	3	2,652	3,25	-0,598	34	60	3	1	1	5	4	4
1	5	1	63	3	2	3,12	3,25	-0,13	40	55	3	1	1	5	4	4
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0	1	0	27	2	1	1,17	1,45	-0,28	15	15	3	1	0	5	3	4
1	4	1	50	3	2	2,652	3,25	-0,598	34	75	1	1	0	5	5	2
1	4	1	50	3	1	3,12	3,25	-0,13	40	70	1	1	0	5	5	2
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0	4	0	39	2	3	0,78	1,45	-0,67	10	40	1	1	0	4	4	4
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0	2	0	52	3	2	0,78	1,45	-0,67	10	40	4	1	0	5	3	2
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0	5	1	50	3	1	1,56	1,65	-0,09	20	25	4	2	0	5	5	10
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0	4	1	70	4	3	0,78	1,45	-0,67	10	15	1	1	0	6	1	4
0	4	1	56	3	1	1,17	1,45	-0,28	15	30	2	2	0	5	3	2
0	4	1	56	3	1	2,34	1,45	0,89	30	30	2	2	0	5	3	2
0	4	1	62	3	1	1,56	1,45	0,11	20	15	3	2	0	7	4	2
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0	4	1	46	3	2	1,95	1,55	0,4	25	30	4	1	0	5	4	4
0	4	1	46	3	1	1,17	1,55	-0,38	15	30	4	1	0	5	4	4
0	3	0	67	4	2	1,56	1,55	0,01	20	45	4	1	1	6	3	2

0	3	0	67	4	1	1,95	1,55	0,4	25	45	4	1	1	6	3	2
0	4	1	22	2	3	2,34	1,55	0,79	30	45	4	3	0	1	3	2
0	4	1	22	2	1	2,34	1,55	0,79	30	45	4	3	0	1	3	2
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0	4	1	64	3	3	1,17	1,45	-0,28	15	15	2	2	2	6	5	2
0	3	0	42	2	3	0,78	1,55	-0,77	10	25	3	1	0	5	3	2
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0	2	1	33	2	1	1,56	1,45	0,11	20	30	4	2	0	5	4	4
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0	3	0	70	4	1	1,17	1,65	-0,48	15	25	3	-999	0	6	2	4
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0	3	0	34	2	1	0,78	1,65	-0,87	10	50	4	1	0	5	4	2
0	3	0	34	2	1	3,51	1,65	1,86	45	50	4	1	0	5	4	2
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0	2	0	31	2	3	2,34	1,55	0,79	30	30	3	2	0	5	5	2
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0	3	1	39	2	2	1,17	1,55	-0,38	15	15	4	3	1	5	4	5
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0	3	1	66	4	1	1,17	1,65	-0,48	15	50	3	1	0	6	3	2
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0	2	0	48	3	1	1,95	1,55	0,4	25	45	3	2	0	5	3	4
0	2	0	35	2	3	0,39	1,45	-1,06	5	35	2	1	0	5	3	2
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0	2	1	54	3	1	1,17	1,45	-0,28	15	30	2	2	0	5	2	5
0	2	1	54	3	1	7,02	1,45	5,57	90	40	2	2	0	5	2	5

0	2	1	46	3	3	1,17	1,55	-0,38	15	25	3	1	0	2	2	8
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0	2	1	56	3	2	2,34	1,55	0,79	30	40	2	1	0	5	5	2
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1	5	0	63	3	2	1,794	1,65	0,144	23	25	2	2	0	5	4	2
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0	5	1	66	4	1	3,51	1,55	1,96	45	45	2	2	0	6	4	4
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1	2	1	70	4	1	1,17	1,55	-0,38	15	25	2	1	0	6	2	4
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0	2	0	22	2	1	2,34	3,25	-0,91	30	75	3	2	0	1	4	2
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0	2	1	46	3	3	1,17	1,45	-0,28	15	15	2	1	0	5	4	5
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0	1	0	29	2	3	1,56	1,55	0,01	20	50	3	1	0	5	5	2
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0	2	0	83	5	1	1,56	1,65	-0,09	20	25	6	3	1	6	3	5
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0	3	1	50	3	3	-999	1,55	-999	-999	30	4	1	0	19	9	4
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0	3	1	50	3	1	0,78	1,55	-0,77	10	30	4	1	0	19	9	4
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0	1	0	54	3	2	1,56	1,55	0,01	20	45	4	2	0	5	3	4
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