Traffic Model in Urban Roads Planning from Surveys and Counts. Application to the City of Badajoz (Spain)

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Abstract. This paper describes the methodology used for the construction of a traffic model in Badajoz (Spain) starting with the allocation of the origin-destination travel matrix derived from surveys and traffic counts conducted in the southern and eastern accesses of Badajoz. The traffic model describes the mobility in potentially-captable future southern traffic relationships and allows the calculation of savings in travelled distance and travel times on the current situation. The traffic model allows to know different behaviours of the possible alternatives in the construction of a new high-capacity road. The model is able to select the one which captures more traffic and produces a bigger saving in travel time, meaning, the one which produces a better socioeconomic improvement. The research concludes in favour of the nearest corridor to the city centre, being this one the more crowded and the one that produces greater time savings. It is also the corridor that allows giving the Southern Bypass a dual purpose of collecting-distributing in the city of Badajoz.

1. Introduction and objectives

The city of Badajoz currently has a population of approximately 150,000 inhabitants. It is the main inhabited centre in Extremadura and it has the characteristics of any European average city. Moreover, its geographical location makes it even more privileged for being a border city and the barycentre of three huge European cities such as Lisbon, Madrid and Seville.

The road network of Badajoz has a radial infrastructure composed by the ensemble of roads which leave the city and whose axes serve as a support of its own growth. The journey of the main road (BA-20) on its way through Badajoz registers about 132,000 trips daily. Here arises the need of building a new southern bypass which allows cars coming from other towns to be linked with the Madrid-Badajoz highway and the rest of the communication roads without entering the city center of Badajoz. The so called Southern Bypass (Ronda Sur) will become an authentic variant of roads which will receive the status of fast track and, together with the highway of Extremadura, will surround the whole city center of Badajoz.

Between 2010-2014, an informative study about Southern Bypass in Badajoz was written where its possible corridors and planning alternatives of the future variant were studied (Figure 1). On October 6th 2014, the Government of Extremadura approved the informative study [1] selecting the first alternative, which was already contemplated in the Badajoz urban planning and which also was the nearest to the city.

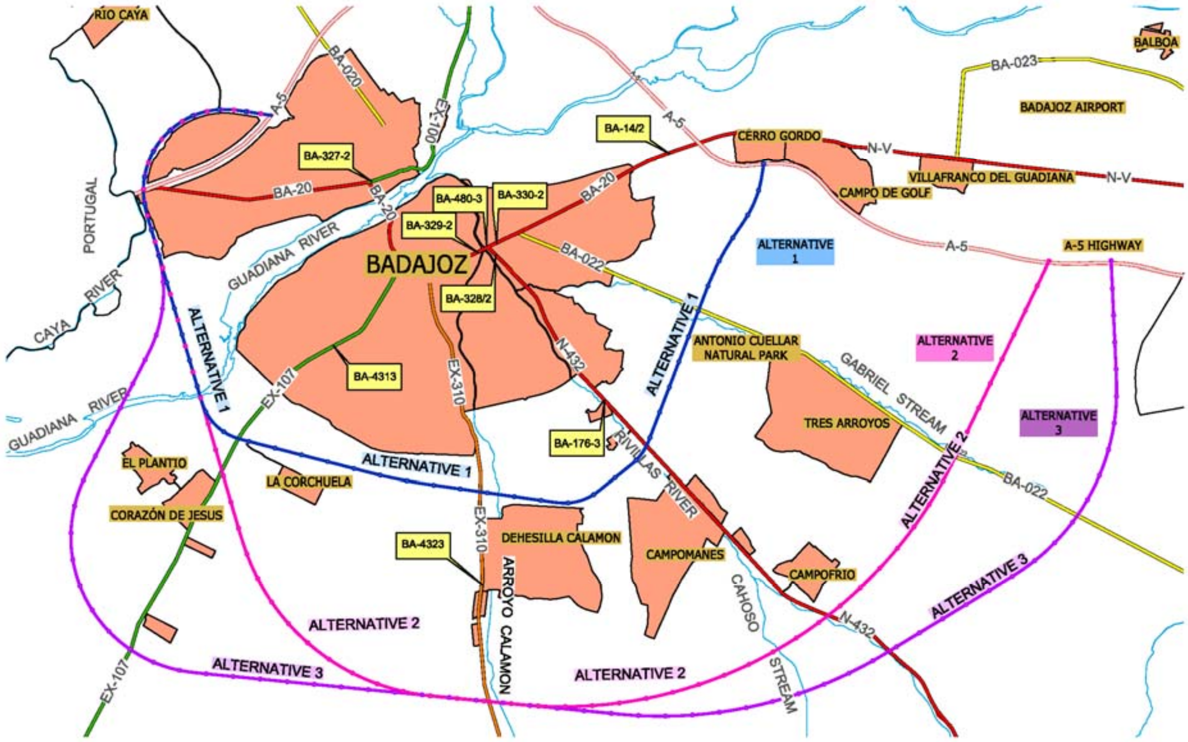

Figure 1. Alternatives studied in the Southern Bypass of Badajoz. In yellow, the nomenclatures of the counting stations considered in this research.

The aim of this research was to create a traffic model for the city of Badajoz which allows knowing different alternatives behavior in the construction of a new high-capacity road. The model is able to select the one which captures more traffic and produces a bigger saving in travel time, meaning, the one which produces a better socioeconomic improvement.

2. Methodology followed for the preparation of the traffic model

The traffic study for the planning of new urban roads is a specially significant chapter, not only because of the necessity of knowing what vehicles are going to circulate on each of these planned alternatives, but also as indispensable data to estimate its social and economic behaviour [2]. It is very important to have the simulation model and allocation from the very beginning of the planning to have knowledge of the traffic that each one of the corridors will capture, creating an extremely valuable auxiliary element for the selection process.

The construction of a traffic model in Badajoz will be done by assigning the origin-destination travel matrix derived from surveys and counts done in the southern and eastern accesses of Badajoz [3]. The traffic model describes the mobility in potentially-capable relationships for a future southern bypass and allows the calculation of savings in travelled distance and travel times in relation to the current situation [4].

The activities done in the construction of the traffic model of the city of Badajoz are enumerated below:

1) Traffic characterization of the Southern Bypass of Badajoz starting from data from the traffic maps of the Ministry of Development[5] and Government of Extremadura [6]. This section is included in appendix A of this paper.

2) A collection and analysis of the information on mobility and traffic in the accesses to Badajoz from the south and east, through surveys and counts. Appendix B includes the selection of locations of surveys and counts and results of surveys and counts made.

3) Estimation of the average daily traffic (ADT) in the specific places of the counts. Appendix C includes average daily traffic (ADT) in the counting locations in 2014.

4) Exploitation of the surveys done and the collection of the results.

5) Process of estimation of the origin-destination matrix in the studied area from the surveys done.

6) Creation of the traffic model of Badajoz and its road's network.

7) Estimation of the traffic captured by each alternative selected for the Southern Bypass of Badajoz. This estimation derives from the assigning of the traveling matrix to each network including the alternative which is the object of the evaluation.

8) Estimation of the traffic collected (vehicles-km) and savings in the travel times (vehicles-hour) in each selected alternative.

2.1. Collecting of information about mobility and traffic

The collecting of information about the demand of transportation has an objective to determine how people move inside the study area, in order to be able to estimate the mobility. The basic data collected for each travel will be in this case the mean of transportation, the origin and destination of the trip.

Willumsen [7] recommends that the generation of the traffic model comes from surveys and counts in situ because they are not highly expensive and constitute the most truthful starting point there can be. Therefore, the basic form of collecting the data has been through origin-destination surveys done in the city center of Badajoz. As a complement, information about the use of networks was collected, through counts with the aim of knowing how supply works, and give information for the exploitation of the surveys.

A total of 3,759 origin-destination surveys took place in the southern accesses of Badajoz which currently channel the potentially-capable traffic for the future Southern Bypass.

2.2. Exploitation of the surveys

The basic aim of the surveys is to obtain the expressive mobility matrix of the transport demand between each pair of zones considered in the division into different areas, which demands its exploitation in a previous step. In the exploitation of the surveys, three basic activities can be pointed out:

- Coding of surveys. It consists on translating numeric data and collected information in the survey, being the origin-destination coding of particularly interest because it is the support of the division in zones of the studied area and the defined area codes [8].
- Calculation of the expansion coefficients. It is about establishing the necessary conversion coefficient to extrapolate the results of the surveys to a part of the vehicles and users (sample) to the total of vehicles and users (universe).
- Collecting of the origin-destination matrix. After coding the surveys, the result is the origin-destination travel matrix which expresses the mobility flow of vehicles classified by type of vehicle and it refers to the universe of vehicles passing through the positions of the survey.

2.2.1. Calculation of the expansion coefficient. The expansion coefficient represents the converting coefficient of the surveyed users (sample) to the total of users (universe) [9]. This expansion coefficient has been calculated for each position of the survey and hour period through the following equation 1

$$EC_{i,h} = \frac{VC_{i,h}}{VS_{i,h}} \quad (1)$$

where:

ECih is the expansion coefficient of the surveys in position *i* during time period *h*.
VCih are the vehicles counted in position *i* during time period *h*.
VSih are the vehicles surveyed in position *i* during time period *h*.

The resulting expansion coefficients in survey positions have been:

Position 1	1.2594
Position 2	1.0996
Position 3.1.	1.1437
Position 3.2.	1.1254
Position 4	1.1161
Position 5	1.2025

2.2.2. Construction of the origin-destination travel matrix in the study area for 2014. The origin-destination travel matrix was obtained through the following process:

1) The expansion of the travel matrix per position of the survey to the estimated ADT in each position of the survey for the year 2014, starting from the expansion coefficients described previously.
2) Correction and rezoning of the matrices per position of the survey, examining each origin-destination relationship and the position of the origin and destination of the trip, adapting the origin and/or destination zones to the survey positions.
3) Obtaining the travel matrix in the study area captured in a single direction in the positions of the survey.
4) Duplication of the connecting trips in the west area of study captured in a single direction in the survey positions.
5) Rezoning of the travel matrix making it a simplified zoning of 78 areas. The selected zones for this simplification have been:

Zones 1 to 65 considered for this count in the municipality of Badajoz.
Zone 66 and 67 Talavera La Real
Zone 68 Access from A-5 (Portugal)
Zone 69 Access through the road of Campo Mayor
Zone 70 Access through the road of Botoa - Valdebotoa
Zone 71 Access through EX -100 road to Cáceres
Zone 72 Access through EX -209 road to Novelda de Guadiana
Zone 73 Access through the road to Talavera La Real
Zone 74 Access through A-5 Mérida - Madrid
Zone 75 Access through BA-903 road to Corte de Peleas
Zone 76 Access through N-432 Seville
Zone 77 Access through EX- 310 Valverde de Leganés
Zone 78 Access through EX -107 Olivenza

The result is the origin-destination travel matrix enclosed in Appendix D.

3. Results and discussion

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3.1. Traffic model in the road network of Badajoz. Condition in 2014 and its future with the commissioning of the Southern Bypass.

The network assigning models simulate the behaviour of a transportation network through the collecting of the traffic loads derived from the travel matrix. This matrix represents the mobility in the study area for a determined year. The traffic which Southern Bypass will capture is obtained from the assigning of the 2014 travel matrix to the defined road network, including in the future situation of the 3 bypass alternatives.

To be able to make a model of the network, a drawing which guaranteed all the possible coherent itineraries between each pair of centroids (representation of the origin and destination network of a journey) was made [10]. The road network of the study area for 2014 was modelled defining the following parameters for each turn in the routes drawing:

- Origin knot
- Destination knot
- Distance between knots
- Type of arc
- Average travel distances
- Circulation directions

8 types of arcs and the following average travel velocities were considered:

1)	Roads in the city centre	15-20 km/hour
2)	Roads in the surroundings	20-35 km/hour
3)	Urban highway	60-80 km/hour
4)	Suburban highway	100-110 km/hour
5)	Urban road	40-50 km/hour
6)	Suburban road	50-75 km/hour
7)	Centroid access	15 km/hour
8)	Bypass	80 km/hour

Cascetta and Ruso [11] express the necessity of adjusting the network (calibration) by checking that the itineraries which allow establishing the modelled network has correspondence with the reality. This calibration is made calculating the minimum-cost paths (time and distance) from a group of selected centroids and checking them with the real ones used by the users in 2014. Van-Vliet [12] does a good collection and discussion about the most important algorithms used for the construction of minimum journeys trees.

Once it was modelled for the year 2014, the future model was made with the commissioning of the Southen Bypass. It was necessary to include the new arcs which describe each of its 3 alternatives. In Figure 2 there is a representation of the road network in 2014 and in Figure 3 there is a representation of the future network with the commissioning of the Southern Bypass.

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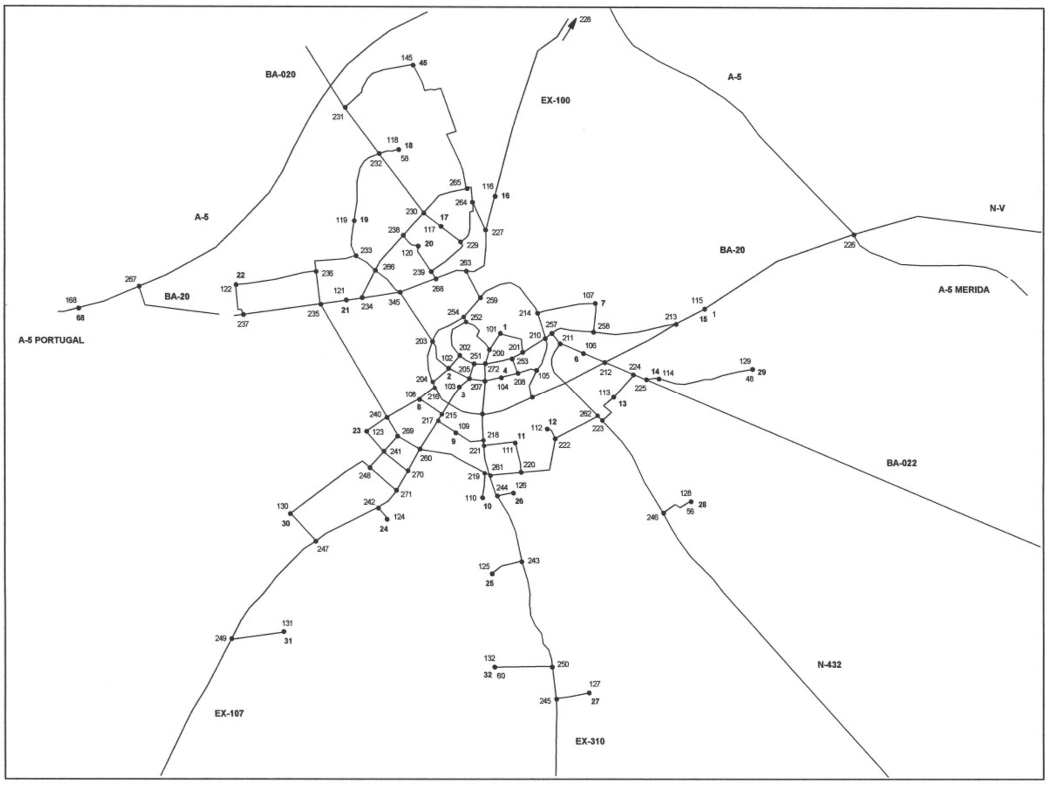

Figure 2. Traffic model of Badajoz city for the year 2014

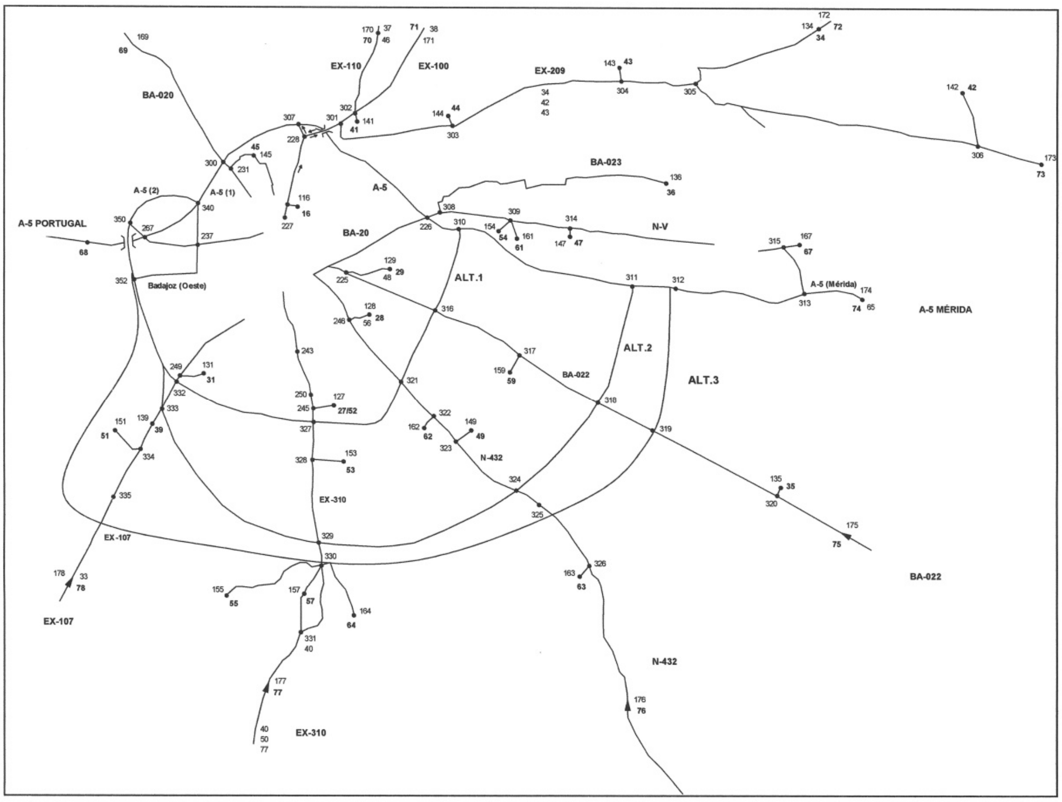

Figure 3. Traffic model in Badajoz city with the commissioning of Southern Bypass

3.2. Traffic captured by Southern Bypass alternatives.

The estimation of traffic captured by each of the Southern Bypass alternatives has been established by the origin-destination travel matrix assignment to the future route network which includes each of the 3 Southern Bypass alternatives. To be able to assign this, there are several methods such as the "all or nothing" or the stochastic method. The stochastic methods of traffic assignment reveal the variability of the users and their perception of the costs and the way of minimizing at the same time the distance and the travel time, therefore, the general costs. These methods could be based in a simulation as in Burrell [13] or they could be proportional. The proportional methods are based on a network load algorithm and distribute the trips which arrive to the node among all the other possible exit knots, contrary to the assigning method "all or nothing" that assigns all trips to an individual exit node.

In this research, the traffic assigning was made using a stochastic proportional method of assigning alternative routes: the Dial method [14]. In this method two or more alternative routes are assigned between each pair of zones, dividing the existing flow between those itineraries, considering the generalized minimum cost (distance + time) and the generalized cost for each of the itineraries. According to the Dial method, the trips in each origin-destination relationship are divided among the different itineraries through a logit type division model. In the equation 2 the simplest case of a logit model is represented, which is the one that only considers two different options to choose from, considering for each trip the characteristics of the generalized cost. In this case, a similar one to the Ortuzar model is used [15] with the same primary and secondary modal split dispersion parameters ($\lambda_1 = \lambda_2$), which makes it a simple multinomial logit model (MNL) [16].

$$p(1) = \frac{1}{1+e^{-\lambda(C1-C2)}} \quad (2)$$

where:

p(1) is the probability of the traveler using itinerary number 1.
C1 is the generalized cost of itinerary number 1.
C2 is the generalized cost of itinerary number 2.
λ is the dispersion parameter. Measuring the model from the known values through the surveys and counts, the value of λ=0.10 has been adjusted.

When C_1-C_2 = 0 it indicates that the utility of both options is the same and the election probability of option 1 is 0.5, which corresponds to the situation of indifference against option 2. When the difference C_1-C_2 acquires increasing positive values, the utility of option 1 increases compared to option 2, and the probability of choosing option 1 tends to unity. When the difference C_1-C_2 acquires negative values indicating the option 2 has better utility than number 1, the probability of choosing option 1 decreases getting close to zero.

In Table 1 the results of this estimations are represented for each of the Badajoz Southern Bypass alternatives.

Table 1. Number of vehicles captured by the Southern Bypass alternatives.

ALTERNATIVE 1										
A-5/ PORTUGAL	928	**EX-107**	2,163	**EX-310**	5,336	**N-432**	2,094	**BA-903**	2,166	**A-5/ MÉRIDA**
ALTERNATIVE 2										
A-5/ PORTUGAL	843	**EX-107**	1,137	**EX-310**	1,803	**N-432**	732	**BA-903**	813	**A-5/ MÉRIDA**
ALTERNATIVE 3										
A-5/ PORTUGAL	463	**EX-107**	601	**EX-310**	1,568	**N-432**	701	**BA-903**	772	**A-5/ MÉRIDA**

3.3. Traffic collected and travel time save.
As complementary information during the process of assigning, it`s been obtained the number of vehicles per kilometre (traffic) and vehicles per hour (travel time) used for the movements through the 3 Southern Bypass alternatives included in the travel matrix. The difference in the traffic captured and the time save is obtained when comparing the parameters of each alternative with those from the network in 2014.

It is important to highlight that the highest socioeconomic profitability alternative will be the one which obtains the highest number of vehicles-km and the least vehicles-hour, for the main reason that this is the one which captures the most traffic and the one producing a bigger time save. The results are represented in Table 2.

Table 2. Differences in vehicles-km (traffic) and vehicles-hour (travel time) between each Southern Bypass alternative and comparison with the network in 2014.

Parameters	Year 2014	ALT-1		ALT-2		ALT-3	
		Value	Difference	Value	Difference	Value	Difference
Vehicle-km	550,926	563,244	+ 12,418	557,395	+ 6,470	554,147	+ 3,221
Vehicle-h	11,226	11,022	- 204	11,141	- 85	11,134	- 92

3.4. Discussion
When evaluating the goodness of the method chosen, it is necessary to comment that the “all or nothing” assigning methods and the stochastic methods don’t take into account the capacity of the roads, assigning higher amounts of traffic in specific stretches which might not have that required capacity. The assigning method per stretches with capacity restriction does take this matter into account [17]. Although, due to the fact that Badajoz is not a city with severe traffic jam problems, the use of models which contemplate the restriction of capacity is not necessary and the use of more simple methods which don’t take this into account seems more adequate, such as the Dial method used in this research.

The chosen method ought to be used in medium-sized cities only without traffic jam problems, because in cities with traffic jam problems, the application of the expansion coefficient constant for the obtaining of the O/D matrix would produce a lot of mistakes [18]. Moreover, as it has been shown previously, mistakes in the traffic assignment considering the lack of capacity in the roads could be made.

It is also necessary to highlight that there are authors who root for zoning-distributing models of the gravitational supply, which are more economical because they don’t require surveys and have demonstrated to be sufficiently precise [19], [20], [21] and [22].

All these conditions make each assigning method have a specific field of application in relation to the characteristics of the assigned network and the problem to analyse and evaluate. In interurban networks, the “all or nothing” and stochastic methods are usually used (Dial method). In urban networks, the capacity restricting methods per stretch are used and, to a lesser extent, the Burrel method. In interurban corridors, with alternative itineraries (toll highway or important variants), the delivery curves are used [23]. This method consists on supposing that between each pair of zones there are at least two alternative ways with their own characteristics of time, distance and level of service. The journeys by the first or the second itinerary are distributed taking into account the already-established delivery curves, which define the percentage by either itinerary according to time saved, distance saved, the travel time ratio, travelled distance ratio, etc. Due to the nature of the variant of Badajoz Southern Bypass, it could be interesting as a future research detour to analyse an alternative model of assignment using this method and compare it to the obtained results in this research.

4. Conclusions

The planning of new roads of high capacity in cities, may they be collective-distributor routes or single variants of the population, requires the generation of an effective traffic model which is able to know the mobility of the current city and simulate the future behaviour with the commissioning of the new route. The design of an adequate traffic model allows to know the behaviour of the different alternatives which are considered possible in the construction of a new high-capacity route, and, in this way, select the one which captures more traffic and produces a bigger saving in the travel times, meaning, the highest socioeconomic profitability.

In this research, it is been described the methodology followed for the construction of a traffic model in Badajoz starting from the assigning of the origin-destination travel matrix derived from surveys and counts. The traffic model describes the mobility in potentially-capable relationships for the future southern variant and allows the calculation of savings in travelled distance and travel times in relation to the situation in 2014.

Analysing the results in Table 4, one might conclude that from the point of view of the traffic, the alternative 1, which is the nearest to the city centre, is preferred to alternatives 2 and 3 since it is the alternative with the highest number of vehicles-km (traffic) and the one with the lowest number of vehicles-hour (less travel time).

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References
[1] Governmentof Extremadura (Spanish). Resolution of October 6, 2014, of the Councilor, approving the public information file and the publication of the "Ronda Sur de Badajoz", Official Journal of Extremadura (DOE), October 9, 2014, 195, pp. 30,469-30,471,2014. Mérida, Spain. Available in http://doe,gobex,es/pdfs/doe/2014/1950o/14062126,pdf, accessed 27/10/2016.
[2] Patriksson, M. Urban traffic planning. “The traffic assignment Problem”. *Models & Methods*, pp.3-6, 2015. New York. Dover Publications, Inc. ISBN: 978-0-486-78790-9.
[3] Cascetta, E. “Estimation of trip matrices from traffic counts and survey data: a generalized least squares estimator”. *Transport Research B*, vol. I8B(415), pp.289-299,1984. doi: http://dx.doi.org/10.1016/0191-2615(84)90012-2.
[4] Ortúzar, J.D., Willumsen, L.G. “Estimating models from traffic counts”. Transportation Models (Spanish), pp.577-604, 2008. Santander: Ibeas-Portilla A, Dell’Olio L (traductores). PUbliCan, Ediciones de la Universidad de Cantabria. ISBN 978-84-8102-512-5.
[5] Ministry of Development (Spanish). "Historical traffic data since 1960 in counting stations”.2015. Madrid. Available in http://www,fomento,es/MFOM/LANG_CASTELLANO/DIRECCIONES_GENERALES/CARRETERAS/TRAFICO_VELOCIDADES/DATOS_HISTORICOS/, Accessed 27/10/2016.
[6] Governmentof Extremadura (Spanish). “AFOEX”. 2015. Mérida. Available in http://fomento,gobex,es/fomento/live/informacion-ciudadano/carreteras/AforosExtremadura,html, Accessed 27/10/2016.
[7] Willumsen, L.G. “Simplified transport models based on traffic counts”. *Transportation* vol. 10, pp.257-278, 1981. doi: http://dx.doi.org/10.1007/BF00148462.
[8] Viegas, J.M.,Guedes-Gomes, F. “Coding of travel origins-destinations and variable zones”. Transit and Transport Engineering. Proceedings of the X Pan-American Congress. Santander: Ministry of Development (Spanish). 1998. Cataloged in WorldCat http://www.worldcat.org/title/ingenieria-de-transito-y-transporte-actas-del-x-congreso-

panamericano-santander-21-al-24-de-septiembre-de-1998/oclc/625616084.
[9] Lederman, R., Wynter, L. "Real-time traffic estimation using data expansion". *Transport Research B*, vol.45, pp.1062-1079,2011. doi: http://dx.doi.org/10.1016/j.trb.2011.05.024.
[10] Kang-Tsung, C., Zaher, K., Yanmei, O. "Effects of zoning structure and network detail on traffic demand modelling". *Environment and Planning B: Planning and Design*, vol.29, pp.37-52, 2002. doi https://doi.org/10.1068/b2742.
[11] Cascetta, E., Russo, F. "Calibrating aggregate travel demand models with traffic counts: Estimators and statistical performance". *Transportation*, vol.24, pp.271–293, 1997. doi: http://dx.doi.org/10.1023/A:1004968411792.
[12] Van-Vliet, D. "Improved shortest path algorithms for transport networks". *Transportation Research*, vol.12(1),pp. 7-20, 1968. doi: http://dx.doi.org/10.1016/0041-1647(78)90102-8.
[13] Burrell, J.E. "Multiple route assignment and its application to capacity restraint". *Proceedings of Fourth International Symposium on the Theory of Traffic Flow*. 1968. Karlsruhe, Germany.
[14] Dial, R.B. "A probabilistic multipath traffic assignment model which obviates path enumeration". *Transportation Research,* vol.5, pp.83-111, 1971. Cataloged in WordCat http://worldcat.org/isbn/1840647973.
[15] Ortuzar, J.D. "Nested logit models for mixed-mode travel in urban corridors". *Transport Research A*, vol.17A(4), pp.283-299, 1983. doi: https://doi.org/10.1016/0191-2607(83)90092-4.
[16] McFadden, D. "Conditional Logit Analysis of Qualitative Choice Behavior". *Frontiers in Econometrics*, pp. 105-145, 1974. New York, Academic Press. Available in https://eml.berkeley.edu/reprints/mcfadden/zarembka.pdf.
[17] Wardrop, J.G. "Some theoretical aspects of road traffic research". *Proceedings of the institution of Civil Engineers*. Part II, vol.1, pp.325-362, 1952.
[18] Yang, H., Sasaki, T., Lida, Y., Asakura, Y. "Estimation of origin-destination matrices from link traffic counts on congested networks". *Transport Research Part B*, vol.26 B(6), pp.417-134, 1992. doi: http://dx.doi.org/10.1016/0191-2615(92)90008-K.
[19] Horberg, P. "Estimation of parameters in models for traffic prediction: a non-linear regression approach". *Transport Research*, vol.10, pp.263-265, 1976. doi: http://dx.doi.org/10.1016/0041-1647(76)90059-9.
[20] Robillard, P. "Estimating the O-D matrix from observed link volumes" .*Transport Research*, vol.9, pp.123-128, 1975. doi: http://dx.doi.org/10.1016/0041-1647(75)90049-0.
[21] Tamin, OZ., Willumsen, L.G. "Transport demand model estimation from traffic counts". *Transportation*, vol.16, pp.3-26, 1989. doi: http://dx.doi.org/10.1007/BF00223044.
[22] Wills, M.J. "A flexible gravity-opportunities model for trip distribution". *Transport research B*, vol.20B (2), pp. 89-111, 1986. doi: http://dx.doi.org/10.1016/0191-2615(86)90001-9.
[23] McLynn, J.M., Woronka, T. "Passenger demand and modal split models". *US Northeast Corridor Transportation Project*, Report 230, 1969.

Appendix A. Characterization of traffic in the surroundings of the southern bypass

In order to characterize the traffic potentially captured by the Badajoz Southern Bypass, we have the data collected in the traffic maps produced annually by the Ministry of Development and the Government of Extremadura. Table A1 includes the stations that provide information on traffic in the southern area of Badajoz with their location, average daily traffic (ADT) and percentage of heavy (P) between the years 2010-2014.

Table A1: *Traffic data and location of selected counting stations [5,6].*

STATION	TYPE	ROAD	K.P.	2010		2011		2012		2013		2014	
				ADT	H	ADT	H	ADT	H	ADT	H	ADT	H
BA-14-2	State/ Secondary	BA-20	0+600	23.374	3.5%	22.258	3.5%	20.681	2.9%	20.055	2.9%	21.833	2.5%
BA-176-3	State/ Coverage	N-432	4+000	11.250	5.9%	9.545	3.5%	9.377	3.9%	9.413	3.6%	5.088	5.0%
BA-327-2	State/ Secondary	BA-20	7+720	32.682	2.5%	29.577	2.3%	30.247	2.3%	31.056	2.3%	30.830	2.3%
BA-328-2	State/ Secondary	N-432	0+470	17.378	4.1%	21.788	3.6%	19.044	3.9%	17.982	3.7%	17.852	3.9%
BA-329-2	State/ Secondary	BA-20	4+550	35.669	3.2%	10.412	23.3%	10.602	12.6%	28.272	3.0%	29.281	2.9%
BA-330-2	State/ Secondary	BA-20	3+990	28.068	3.9%	23.994	3.2%	22.597	3.0%	24.686	2.5%	23.962	2.4%
BA-480-3	State/ Coverage	N-432	0+500	9.195	5.9%	10.298	4.1%	9.914	4.1%	9.433	4.8%	9.414	4.2%
E-222-0	State/ Permanent	N-432	8+110	7.977	5.9%	7.641	6.0%	7.418	5.4%	7.227	5.2%	7.113	5.0%
BA-0170	Autonomy/ Semiperm.	EX-107	23+00	7.403	5.0%	6.740	4.3%	6.210	5.1%	6.242	6.5%	6.185	4.5%
BA-2282	Autonomy / Coverage	EX-310	12+00	2.040	5.0%	2.195	3.4%	1.876	3.0%	1.957	3.8%	1.983	4.3%
BA-4313	Autonomy / Coverage	EX-107	3+000	8.822	5.0%	9.382	13.0%	7.970	3.8%	7.133	6.6%	7.630	3.6%
BA-4323	Autonomy / Coverage	EX-310	7+000	3.197	6.0%	3.707	7.0%	3.001	4.3%	3.052	6.9%	3.072	4.3%

Figure 1 represents in yellow the location of all the stations that are within the study area. The stations BA-0170, BA-2282 and E-222-0 are outside the study area and are not shown in the figure. The BA-2282 is relatively close to the study area and provides traffic data of interest. The BA-0170 and E-222-0 are further away, however since they are semipermanent or permanent; they have been taken into account in the research conducted.

To characterize the seasonality of the traffic in the state network, part of the data of the permanent station E-222 is the most reliable. The summary of this station is as follows:

- The maximum average traffic in the working day is in November, 6.4% higher than the average traffic on a working day.
- The minimum average traffic in the working day is in January, 8.0% lower than the average traffic on a working day.
- Traffic on the H100 (traffic matched or exceeded 100 hours per year) is 691 vehicles / hour, equivalent to 8.4% of ADT with 3.17% heavy, which means 44.9% of the percentage of heavy annual average (7.06%).
- Weekend traffic is less than weekday traffic, 78.7% of traffic on a business day.

For the autonomic network, the seasonality of the traffic is made from the semi-permanent station BA-0170, whose data are summarized below:

– The maximum average traffic in the working day is in September, 6.9% higher than the average traffic on a working day.
– The minimum average traffic in the working day is in January, 14.0% lower than the average traffic in the working day
– Weekend traffic is lower than traffic on a weekday, 73.4% of traffic on weekdays.
– The points of traffic appear from 8 to 9 am (7.35% of ADT), from 14 to 15 (7.46% of ADT) and from 18 to 19 (6.69% of ADT).

Appendix B. Selection of locations for surveys and counts. Surveys and counts made.

B.1. Selection of locations for surveys and counts.

For the selection of locations for the surveys and counts inside the group of road's accesses to Badajoz in the south and east, locations with traffic lights were selected so that the count could take place while every vehicle was still. After a view of the study area, five survey points were selected (Figure B1), and are listed as follow:

Point	Location
P1	EX-107. Avenue Luis Movilla Montero (Neighborhood of Llera).
P2	EX-310. Avenue Damián Téllez Lafuente crossing with BA-20.
P3	N-432 crossing with Avda. Luis de Góngora.
P4	BA-022 (Corte de Peleas road) crossing with BA-20.
P5	BA-20 (Avenue Juan Sebastián el Cano) crossing with BA-022.

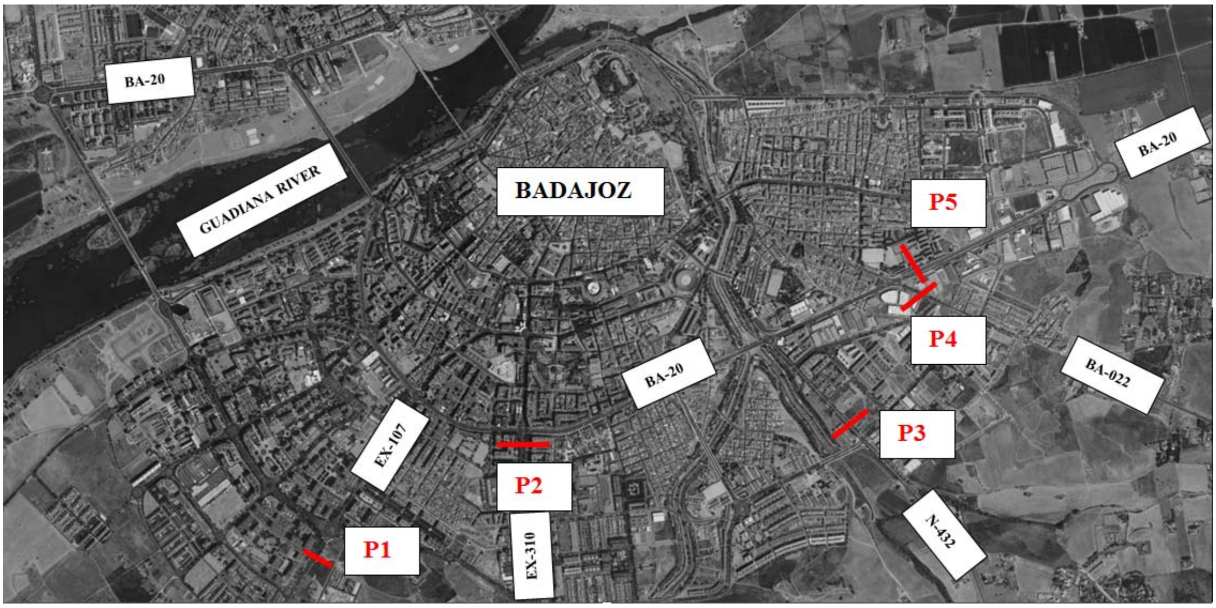
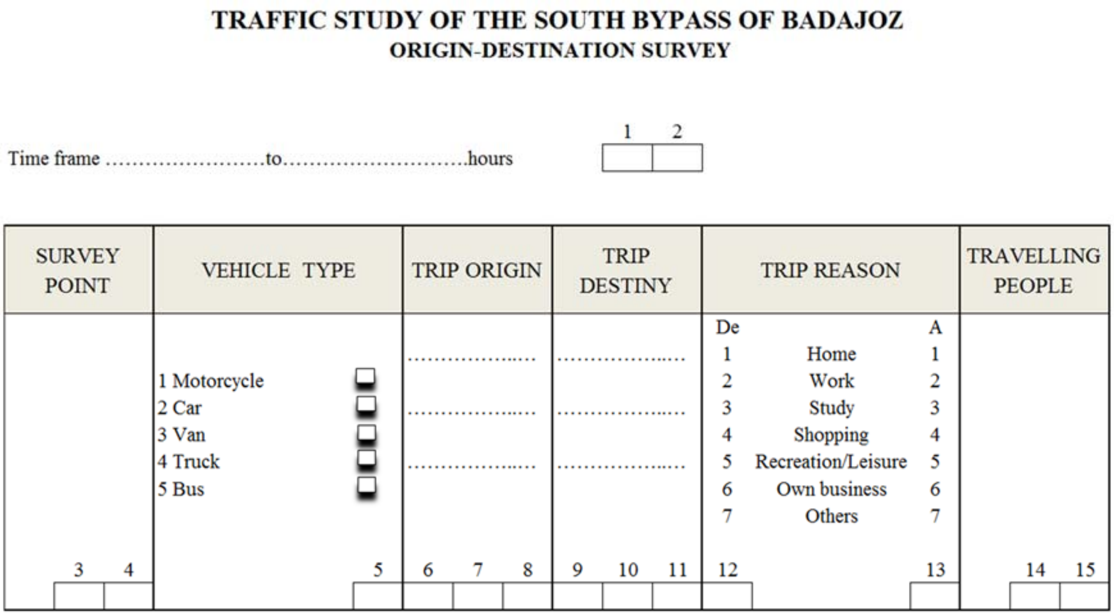


Figure B1. Location of the position of the survey points.

B2. Origin-destination surveys.

The origin-destination surveys were taken on Wednesday, October 5th, 2011, from 8 a.m. until 8 p.m., using the questionnaire in Figure B2 [B1].


TRAFFIC STUDY OF THE SOUTH BYPASS OF BADAJOZ
ORIGIN-DESTINATION SURVEY

Time frame ……………………to………………………hours 1 2

SURVEY POINT	VEHICLE TYPE	TRIP ORIGIN	TRIP DESTINY	TRIP REASON	TRAVELLING PEOPLE
	1 Motorcycle 2 Car 3 Van 4 Truck 5 Bus	……………… ……………… ………………	……………… ……………… ………………	De A 1 Home 1 2 Work 2 3 Study 3 4 Shopping 4 5 Recreation/Leisure 5 6 Own business 6 7 Others 7	
3 4	5	6 7 8	9 10 11	12 13	14 15

Figure B2. Survey template used.

3,759 surveys took place with the next distribution per position of the survey:

Position	Surveys number
Position 1	616 surveys
Position 2	604 surveys
Position 3	705 surveys
3.1. Straight movement	324 surveys
3.2. Turn in Luis de Góngora	381 surveys
Position 4	495 surveys
Position 5	634 surveys

B3 Counts.
Simultaneously to the realization of the surveys, a 16-hour count (from 6 to 22 hours) was made of the counted journeys.

References

[B1] Bonsall, P.W., O'Flaherty, C.A. "Observational traffic surveys". *Transport planning and traffic engineering* ,4th edition, pp.232-251, 1997. London: Arnold. ISBN 0-340-66279-4.

Appendix C. Average daily traffic (ADT) in the counting locations in 2014.
Firstly, data is updated from surveys and counts made in 2011. Since there has been no significant change in population, nor modifications in the route network, data from 2011 is considered valid for 2014. The counts have an annual accumulative growth of 1.08% applied to them, which is the recommended value by the Ministry of Development [C1]. Between 2011-2014 a coefficient of $(1.0108)^3$=1.033 is applied. Afterwards, it's necessary to translate the counts of 16 hours to a working day in the month of October to an ADT from 2014. Therefore, the monthly variation coefficients (L), the night coefficients (N) and Saturday/Sunday (S) coefficient starting should be applied from the counting stations located in the proximities [C2].

In the position 1 of the survey, located in the EX-107 road, data from station BA-0170 (located in Olivenza) and from BA-4313(located in Badajoz) are taken into account. The year 2014 gets the following results:

–	Average daily traffic in October (BA-0170)	6,470
–	ADT (BA-0170)	6,185
–	Monthly variation factor (L)	L=6,185/6,470=0.956
–	Saturday/Sunday variation (S) of BA-0170	0.924
–	Traffic in 16 h (6 to 22) in an average working day (BA-4313)	8,684
–	Traffic in 24 h in an average working day (BA-4313)	9,291
–	Night factor (N) of BA-4313	N=9,291/8,684=1.07

To obtain the value of ADT in position 1, from the count of 16 hours in a working day of the month of October, the factor is F=N·L·S= 1.07·0.956·0.924 = 0.945. The ADT in position 1 will be ADT1=10,256·1.033·0.945=10,012. In position 2, located in the EX-310, data from the BA-2282 and BA-4323 stations (located in Badajoz) are taken into account. The 2014 data from this location is enclosed below:

–	Average daily traffic in October (BA-2282)	2,198
–	ADT (BA-2282)	1,983
–	Monthly variation factor (L)	L=1,983/2,198=0.902
–	Traffic in 16 h (6 to 22) in an average working day (BA-4323)	3,739
–	Traffic in 24 h in an average working day (BA-4323)	3,937
–	Night factor (N) of BA-4323	N=3,937/3,739=1.053

The S factor of Saturdays and Sundays is taken as 0.924 which is given by the station BA-0170 since the nearest two stations don’t have it. Thus, to obtain the value of ADT in position 2 from a count of 16 hours in a working day from October the factor F=N·L·S= 1.053·0.902·0.924 = 0.878 is obtained. The ADT in position 2 will be ADT2=9,583·1.033·0.878=8,692. Operating in the same way for position 3, data used belongs to the secondary station BA-328 having for 2014 the next coefficients: L=0.943, N=1.04, S=0.949 thus F=N·L·S = 1.04·0.943·0.949= 0.931. The ADT in point 3.1 will be ADT3.1=4,239·1.033·0.931=4,077. The ADT in point 3.2 will be ADT3.2=2,978·1.033·0.931=2,864.

For position 5 it’s been used the same method using as a reference the station BA-14 whose coefficients for 2014 are: L=0.929, N=1.14, S=0.943 thus F=N·L·S = 1.14·0.929·0.943= 0.999. The ADT in position 5 will be ADT5=12,372·1.033·0.999=12,767.

Lastly, for position 4, due to the proximity to positions 1 and 2 we take the average value between them as valid. This is F1=(F2+F3)/2=(0.945+0.878)/2=0.912. The ADT in position 4 will be ADT4=4,312·1.033·0.912=4,062.

References

[C1] Ministry of Development (Spanish). "Traffic prognosis. Prescriptions and technical recommendations for carrying out traffic studies of Information Studies, Preliminary Projects and Road Projects ". Service Note 5/2014, July 11, 2014, pp.17-20, 2014. Madrid. Available in: http://www.fomento.gob.es/NR/rdonlyres/8F18424F-91CD-412D-9748-F739C67D7DD8/126013/NS52014.pdf, accessed 10/11/2016.

[C2] Kramer, C., Pardillo, J.M., Rocci, S., Romana, M.G., Sánchez, V., Del Val, M.A. "Traffic studies. Road Engineering " (Spanish). Volume I, pp.86-89, 2003. Madrid: McGraw-Hill. ISBN: 84-481-3988-7.

IOP Conf. Series: Materials Science and Engineering **245** (2017) 042013 doi:10.1088/1757-899X/245/4/042013

Appendix D. Origin/Destination Matrix.

The construction of the origin-destination travel matrix in the study area for 2014 is explained in section 2.2.2. The results are shown in table D1.

Table D1 (a). Origin-destination travel matrix in the city of Badajoz. Year 2014. Zones 1-30.

O/D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1																				12										
2	43																													
3	27															15														
4	38										12					11					12	21								
5																				15										
6	12	15									17	15								6										
8	24	15	11				26						15																	
9	19	11	38	40			74						12		29					11			31					15		
10	166	37	151	29	46	73	35								19		11		15	23	28	12								
11	227	71	94	75	13	41	21	13	27		15	14	12				11	12	70	89	54					14	11			
12	14		13	33																										
13	25	6	27	11	14	3		5	22	8	40	27					15						98	22	13	4				
14	103	77	95	51	28	224	748	44	36						108	31	18	35	86	168	30	31	138	24	41		12	73		17
15	376	152	294	146	99	597	146	210	82	54	206	98	377	273		32	85	19	14	261	100	48	620	123	165	50	63	132	71	
16			29	11		19							14	31	32				15											
17										11	11		15	18	85								15	76		15		30		
18											12			35	19								14	7	23					
19										15	70			86	14	15								194	12			125	19	16
20	12				15	6			11	23	89			168	261								24	252	12	80		59	5	
21				12						28	54			30	100									12				20	6	
22				21						12				31	48									184	22			72		
23	85		22	147		51	45		31	13	27	12	98	138	620		15	14		24				1145				179	8	
24	370	387	545	173	72	26	550	187	248	33	222	100	71	39	65		76	7	194	252	12	184	1145	50	16	40	13	131		
25	456	170	322	92	23	27	61		11		12				11			23	12	12		22								
26	170	27	112	48	26	11	40				15				11		15			80										
27	56	48	30	15				19																						
28	237	108	109	111	41	46	380	65	92	42	69	71	120		58		30		125	59	20	72	179	43	107	45	8			5
29	26	30	21		13	30	112					7			17				19	5	6		8							
30	7		16					15											16						13					
31																			12				16							
32	336	94	242	90			50		11		38						23		32	14								11		
35	5	9				20	8												15	9		6								
36											33																			
37						18																								
41							36				19			50	25									31				19		
42											32																			
44																							19							
46	14			25											13															
47	31	20	73			15				15	14		29		14						20		15							
48			6			9	44				6								9	6	6		6							
49	35	17	17				9	14		9	6	5			8			6			5	5	6	16	5					
50						11				4												17								
51	86	102	90	12	27	15	71	22	27		87		27				15					18	140	50	12	105				
53	37		11	44			14				21		12							28		11		11						
54	20		46	14		15		14	8			18			25						14		43							
55	15		15				14																							
59	35	17	41		30	69	91				6					6			17	44	5		12							
61	131		75	76	63	99	58	87	113	19	54		19	32	18	20	19	19	37	187	45	88	286			29	19	14	14	
62	47	22	24		11		136	18			44	13	19				20		30	16	22		23	13						
63			7				8		9			16								11										
64				17																										
65	34		120			27	67		20				30				15		18	34	53		88		34			18		
67	27	11	58	38		34	55	19		19			43						19	19	25	39	185	20	14					
68													8	18	19									16		14				
74	496	101	212	77		156	146	70	123	15	371	125	18	128	60		24		180	77	36	200	261	61	5	5				14
75		6	6		11	6	29				8									7	6					6				
76	396	163	116	77	28	116	161	78	116	27	267	33	61		81	23	33		223	78	87	221	283	16	28	4				5
77	198	95	127	69	34	51	70	20		15	36			17	19		23				11									
78	195	425	217	101			210	23	29	18	271	31	33		48		7		71	55		49	477	38	67	64		48		
TOTAL	4631	2236	3432	1655	594	1815	3515	923	1016	380	2184	585	1033	1094	1827	153	455	135	1229	1602	597	1044	4132	2404	589	475	126	946	123	57

IOP Conf. Series: Materials Science and Engineering **245** (2017) 042013 doi:10.1088/1757-899X/245/4/042013

Table D1 (b). Origin-destination travel matrix in the city of Badajoz. Year 2014. Zones 31-78.

O/D	31	32	34	35	36	37	38	39	41	44	46	47	48	49	50	51	52	53	54	55	59	61	62	63	65	67	68	69	70	73	74	75	76	77	78	TOTAL
1																																				12
2																																				43
3																																				42
4																																				94
5																																				15
6																																				65
8											14															15										120
9												12									27					11					30		11			371
10																					13	23				15				19	88					803
11				11								23										12							31		185		28			1174
12																															13					73
13		8																									8				74			5		435
14			34		7	6			22	12	20									7		150			29	42	18		8		90				27	2690
15		45		15				36	20										13		111						19		19		33		33		133	5370
16																					6	20											23			200
17		23														15						19	20		15						24		33	23	7	455
18														6								19														135
19	12	32		15									19								17	37	30		18	19					166		163		71	1165
20		14		9									6					28			44	187	16	11	34	19					77	7	78		55	1602
21												20	6	5					14		5	45	22		53	25					36	6	88			587
22				6									5		17	18		11				88				39					200		221		49	1044
23	16								15	19		28	6	6		140			43		12	297	23		88	185					272		283		477	4584
24		45				17					18										34	41				46	16				90		48			5563
25												13										14				12					105	15				1413
26									27																		14				19					615
27																										19		19								206
28	5	53					8	8	8		37	9				6	6				7	22				20		8		18	65		6	5	27	2560
29												6										11							8		24		6		8	357
30		16																																		83
31																																				28
32					15							23																			34					1013
35																						5						6								83
36																																				33
37																																				18
41																							31										25			236
42																																				32
44																																				19
46																																				52
47																																			44	290
48								8														5									5					110
49											8															20					8					199
50																																				32
51																		12													41		31	27		1017
53										11																										200
54																																	25			242
55																																				44
59									6													16									6					401
61																											37								65	1723
62									9							8						20				25					20					540
63									4																											55
64																																				17
65																																				558
67																					18						18								33	694
68																						37				18					33		239		12	414
74	13	15							19												19						33				4			8	53	3125
75																						6			6						8					105
76		12							20													45				9	239	12	15		94				6	3173
77			43						17		19											8				11		14			29				19	945
78		27										16							16			14					12			16	138		15	7		2738
TOTAL	46	290	77	56	22	23	8	52	167	42	116	150	42	17	17	187	6	51	86	7	313	1141	142	11	243	550	414	59	81	53	2011	28	1356	75	1086	50012