Tech Memo

DATE: October 20, 1999.

PROJECT: **Estudio Integral de Transporte (III)/ Multimodal Transportation Study:** Development of Travel Demand and Mobile Source Emissions Models for base year 1996, Juarez. (Contract No. 9880055000)

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SERIAL: EITIII-04

SUBJ: Progress under Task 4:
Traffic Assignment Application.

Overview

Under the current project five specific tasks have been outlined for development:

1. Trip generation model application
2. Trip distribution model application
3. Mode split model application
4. Traffic assignment application
5. On-road mobile source emissions modeling

Having completed tasks 1 to 3, the present Tech Memo summarizes the work performed to accomplish the traffic assignment model application, concluding with it the travel demand modeling part of the current project.

Background

At the traffic assignment step, the O-D trip matrices by mode developed at the trip distribution/mode-split steps are loaded onto their respective mode-specific networks. This is done through algorithms that under a least travel-cost criteria select specific routes of the networks to channel the O-D flows. The result is then an estimation of traffic accumulated on each link of the networks.

There are several approaches for assignment of flows to the networks, and in general terms these have as premise the consideration or not of capacity restraint of network links (i.e. route congestion), and the assumption or not of stochastic effects.

<u>Capacity restraint concept</u>

This concept assumes that traveler choice is affected by the level of congestion of the possible routes connecting origin and destination. Therefore any model adopting this concept requires functions relating flow to the cost of travel on a link (e.g. time), also known as link performance functions. If link capacity is not taken into account, a route is considered to yield a constant cost regardless of the traffic being accumulated; under such condition one route ends up concentrating the entire flow of the O-D pair (i.e. All-or-nothing).

<u>Stochastic effect concept</u>

This effect considers the fact that travelers do not posses perfect information about the transportation system, thus, resulting in a variable perception of the networks which in turn leads to a spread in the choice of routes for each O-D pair. Although a more realistic approach, the use of this concept requires something close to an actual data sample on the choices of routes selected by travelers in the study area; for the Juarez case this information is currently not available.

Depending on the use of these two concepts, Table 1 shows the four common approaches to traffic assignment.

Table 1. General approaches for traffic assignment.

		Considers stochastic effects	
		NO	YES
Considers capacity restraint	NO	All-or-nothing	Pure stochastic
	YES	User equilibrium (UE)	Stochastic user equilibrium (SUE)

The selection of a particular method depends mostly on the available data, the level of accuracy sought, and the specific modes being analyzed. Regarding this last point, it is important to underline though that since the final objective of the current project is to model mobile source emissions, the assignment step was focused on motorized vehicle flows only (AUTO generic mode), thus the algorithms used herein are specifically tailored for vehicle traffic assignment on the roadway network. As such the method selected was a capacity restraint non-stochastic approach known as User Equilibrium (UE). Using this method the system reaches an equilibrium state as defined by Wardrop:

> ***Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip maker can reduce his path costs by switching routes.***
> ***...all used routes between an O-D pair have equal and minimum costs while all unused routes have greater or equal costs.***

Obviously this can only be possible if all trip makers perceive costs in the same way (no stochastic effects).

Input for UE vehicle traffic assignment

Running UE vehicle traffic assignment in TransCAD is a simple and straight forward process, requiring the following three pieces of information:

1) Parameters for link performance function
2) Roadway network with attributes
3) O-D trip matrix

<u>Parameters for link performance function</u>

The link performance function is a mathematical representation of the relation between flow (i.e. traffic volume) and travel cost (i.e. travel time) for any given link in the network. A widely used link performance function is the formulation suggested by the Bureau of Public Roads (BPR), which is stated as follows:

$$t = t_f \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right] \qquad \textbf{(Eq. 1)}$$

Where:

t : Congested link travel time.
t_f : Link free-flow travel time.

v : Link volume.
c : Link capacity.
α : Calibration parameter (0.15 used here).
β : Calibration parameter (4.00 used here).

The BPR formulation is the default link performance function provided in TransCAD. Here link travel time is basically a function of the traffic volume/capacity ratio, and in an iterative process its value is updated as traffic volume builds up. The function has two global calibration parameters α and β that shape the s-curve of the function, and are commonly given values of 0.15 and 4.00 respectively. These two values are provided as network attributes, constant for all links.

<u>Roadway network with attributes</u>

In addition to α and β which are constant-value attributes for all links, it is necessary to specify two more link-specific attributes: 1) free-flow travel time t_f, and 2) link capacity **c** . The values of these attributes are highly correlated to the area type where the link is located, and to the functional classification of the link. In this regard TxDOT has developed for the El Paso study area a speed & capacity look-up table based on field observations and previous calibration efforts, which IMIP has adjusted for use on the Juarez model as an initial approach. The adjustment consisted at this stage simply in providing an adequate equivalency between area types from both cities based on activity density ranges, thus for example a RURAL classification for Juarez would more closely be equivalent to a SUBURBAN RESIDENTIAL classification in El Paso. Table 2 depicts the selected equivalencies, and Table 3 depicts the resulting Speed & Capacity look-up table for Juarez. Since functional classification is the same for both models, there is no need for adjustment here.

Table 2. Initial area type equivalencies.

Area Type Juarez	Activity Density range	**Equivalent Area Type El Paso**
RURAL	0-26	**SUBURBAN RESIDENTIAL**
SUBURBAN	27-62	Between **FRINGE** and **CBD**
URBAN	63-135	No equivalency but use **CBD**
CBD	136+	No equivalency but use **CBD**

Table 3. Preliminary Speed & Capacity (per lane) look-up table for Juarez.

Speed (mph) Capacity (vpl)		**Area Type**			
		CBD (1)	Urban (2)	Suburban (3)	Rural (4)
Functional Classification	Conn (0)	15 30000	15 30000	25 30000	35 30000
	Expy (3)	32 13100	32 13100	29 11750	36 10250
	PartD (4)	12 8350	12 8350	24 7500	31 6250
	PartU (5)	12 7500	12 7500	23 6800	37 5600
	MartD (6)	11 7250	11 7250	19 6500	29 4050
	MartU (7)	12 6600	12 6600	20 5950	31 3750
	MartUnp (8)	11 6200	11 6200	17 5550	28 3350
	Ramp (12)	20 18000	20 18000	18 18000	34 18000

The speed values in Table 3 are essentially average 24-hr free flow speeds that having been assigned to the network links, are then converted to free-flow travel times (minutes) through the use of each link's length.

Capacities in Table 3 are also expressed as 24-hr traffic capacities per lane, which should be multiplied by the number of lanes of each link to calculate link capacity. Although not intuitive in its definition, 24-hr capacities are necessary in order to perform daily assignment, being consistent with the O-D trip data which is also provided as daily averages.

The links in the entire TransCAD roadway coverage were provided with these two additional attributes, and the network was redefined to include the additional fields for problem solving, and final traffic assignment.

O-D trip matrix

At this point of the travel demand modeling process, O-D trip matrices disaggregated by purpose and mode have been developed. As previously stated, since the focus of the project is on the vehicular traffic assignment, the AUTO generic mode matrices were first of all converted from person-trips to vehicle-trips using the following vehicle occupancies:

HBW 1.25 pax/veh
HBNW 1.87 pax/veh
NHB 1.72 pax/veh
TRTX 1.44 pax/veh
EXLO 1.41 pax/veh

These averages by trip purpose were previously obtained from the household travel survey[1].

Following the conversion process, the matrices were then added, obtaining a single O-D trip matrix for vehicular flow. Table 4 presents the resulting O-D matrix, with the slight variation that the 438 TAZs in the Juarez study area (425 internal, 13 external) have been aggregated here into 10 sectors just for summary purposes. As shown, Juarez had in 1996 around 1.02 million vehicle-trips per day. Sectors 9 and 10 aggregate the flows from external zones on the US and Mexico respectively.

Table 4. Summary O-D trip matrix for daily vehicular flow (aggregated in 10 sectors).

Matrix1 - OD TOTAL96aut (24hr VEH TRIPS) Aggregate (Matrix 1 (0-24))

	1	2	3	4	5	6	7	8	9	10	Sum
1	19069	45838	4008	15950	347	56	56	567	1761	20	87672
2	45838	83614	13431	32745	6092	706	481	2380	15710	489	201487
3	4008	13431	49435	30740	13278	525	1720	31	2395	717	116280
4	15950	32745	30740	144784	55062	7748	2339	1007	15870	1045	307290
5	347	6092	13278	55062	90903	18297	5850	4	2008	3224	195066
6	56	706	525	7748	18297	10165	183	0	810	888	39376
7	56	481	1720	2339	5850	183	5201	0	410	824	17065
8	567	2380	31	1007	4	0	0	334	23	0	4346
9	1761	15710	2395	15870	2008	810	410	23	0	1363	40349
10	20	489	717	1045	3224	888	824	0	1363	24	8593
Sum	87672	201487	116280	307290	195066	39376	17065	4346	40349	8593	1017523

Also as a schematic example of the magnitude of these flows, Figure 1 shows the desire-lines from and to sector 2. Appendix A shows the desire lines for all the other sectors.

Traffic assignment output

TransCAD yields two main results from the UE traffic assignment routine: 1) traffic flow by link, and 2) loaded (congested) link travel time. In this regard, Figure 2 shows a thematic map for the Juarez 96 roadway assignment, depicting the magnitude of daily traffic flows on the network links (proportional to the width of the links); in addition the color of the links depict the level of link congestion through the v/c ratio. Since all the input data has been provided in terms of daily flow, the resulting assignment also provides results as daily

[1] Tech Memo EITII-06 (Rev 01), "Network processing", IMIP (September 1999).

averages. Thus the link traffic should be read as vehicles-per-day, and the travel time although in minutes, depicts the 24-hr average.

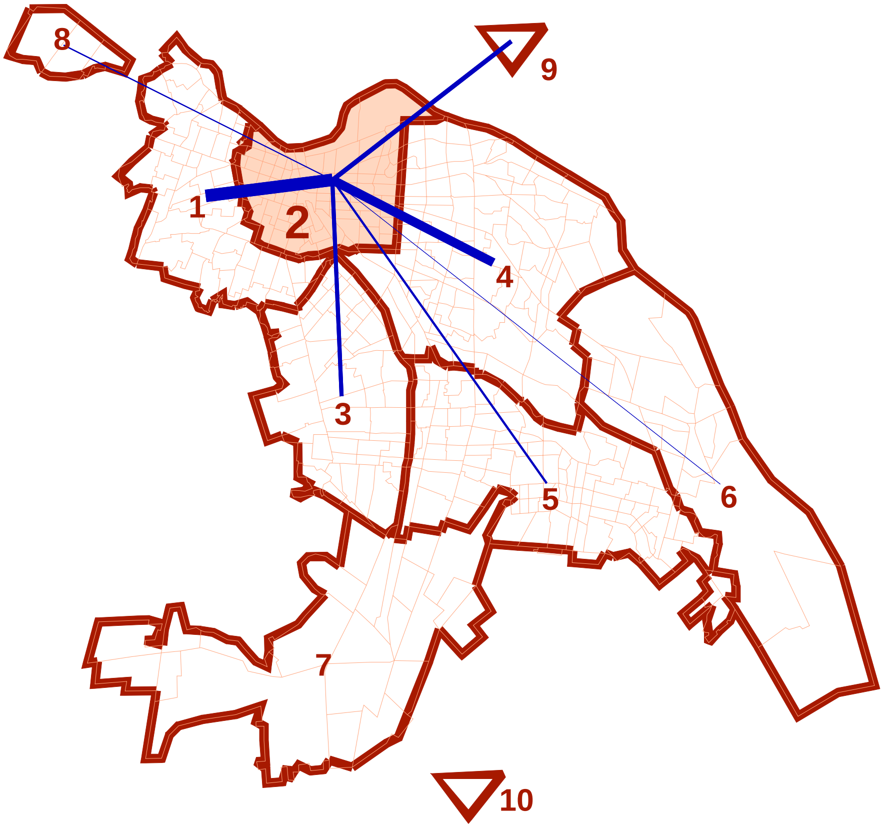

Figure 1. Desire-lines to and from sector 2. Flows <1000 veh/day not shown.

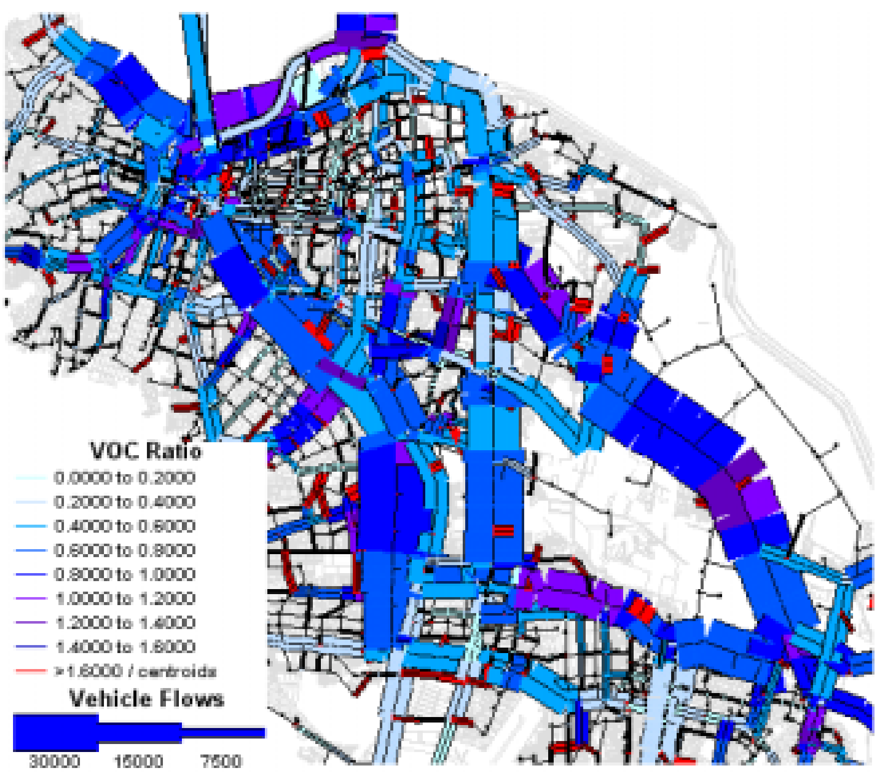

Figure 2. Map of network with “daily” traffic assignment (Juarez 1996).

Assignment validation

Having assigned traffic onto the network, it is always important to compare model results to actual traffic on the roadways in order to establish the level of accuracy by which the model is representing real-life conditions. Depending on the model premises, this comparison can be made at the link, corridor, or screen-line level. If necessary, adjustments to the model can be made all the way back to the trip generation step, or even to the network development assumptions. In the case of the Juarez efforts, results from every step of the model have in general been consistent with preliminary field indicators obtained from previous studies, yet since the speed & capacity table attributes were borrowed from the El Paso model, it is important to check if these yield an appropriate assignment, and asses if adjustments to the table can be enough to validate the counts in the field.

It is important to underline here that due to budget and logistics constraints, traffic counts on the base year were undertaken successfully for only a small number of sites. The goal therefore was to at least run a cordon count validation. Table 5 shows a comparison of counted to modeled traffic flows accumulated at equivalent cordon borders.

Table 5. Comparison of modeled traffic to measured traffic on different corridors.

Corridor	Direction of flow	Cordon border	Model by-direction	Count by-direction	**Total Model**	**Total Count**	**error**
Corr H.C.M-16 de septiembre	W-E	Calle Costa Rica	37,571	49,465	74,998	91,500	18.0%
Corr H.C.M-16 de septiembre	E-W	Calle Costa Rica	37,427	42,035			
Corr 16 de Septiembre	W-E	Av. Fco. Villa	20,676	10,182	34,386	27,674	-24.3%
Corr 16 de Septiembre	E-W	Av. Fco. Villa	13,710	17,492			
Av. Insurgenets	W-E	Eje N-S	11,959	10,291	22,794	19,451	-17.2%
Av. Insurgenets	E-W	Eje N-S	10,835	9,160			
Blvd. Municipio Libre	W-E	Calle Beta	9,474	8,960	19,599	17,577	-11.5%
Blvd. Municipio Libre	E-W	Calle Beta	10,125	8,617			
Av. Hermanos Escobar	W-E	Av. Perez Serna	4,127	6,349	8,386	15,404	45.6%
Av. Hermanos Escobar	E-W	Av. Perez Serna	4,259	9,055			
Av. Manuel Clouthier	W-E	Av. Centeno	12,567	13,129	24,809	27,541	9.9%
Av. Manuel Clouthier	E-W	Av. Centeno	12,242	14,412			
Blvd. Gomez Morin	W-E	Calle R. Rayon	8,660	3,990	17,464	7,847	-122.6%
Blvd. Gomez Morin	E-W	Calle R. Rayon	8,804	3,857			
Av. Carlos Amaya	W-E	Eje N-S	21,581	5,428	43,094	12,258	-251.6%
Av. Carlos Amaya	E-W	Eje N-S	21,513	6,830			
Carretera a Casas Grandes	W-E	km 30	739	688	1,478	1,729	14.5%
Carretera a Casas Grandes	E-W	km 30	739	1,041			
Av. De los Aztecas	N-S	Calle Tzetzales	9,288	10,744	18,888	20,256	6.8%
Av. De los Aztecas	S-N	Calle Tzetzales	9,600	9,512			
Eje N-S	N-S	Av. Rivera Lara	15,029	15,249	29,458	29,119	-1.2%
Eje N-S	S-N	Av. Rivera Lara	14,429	13,870			
Av. Lincoln	N-S	pyramids	10,133	15,249	16,748	29,839	43.9%
Av. Lincoln	S-N	pyramids	6,615	14,590			
Av. A. Lopez Mateos	N-S	Av. Malecon	8,339	4,339	16,444	12,123	-35.6%
Av. A. Lopez Mateos	S-N	Av. Malecon	8,105	7,784			
Av. P. Elias Calles	N-S	malecon	5,284	5,267	10,695	9,676	-10.5%
Av. P. Elias Calles	S-N	malecon	5,411	4,409			
Av. Perez Serna	N-S	hnos escobar	18,383	21,139	36,029	50,370	28.5%
Av. Perez Serna	S-N	hnos escobar	17,646	29,231			
Carretera Juarez-Chihuahua	N-S	km 30	3,395	3,637	6,790	7,274	6.7%
Carretera Juarez-Chihuahua	S-N	km 30	3,395	3,637			

As seen here, most of the differences fall below the 25% error level, although for a couple of cases the error gets considerably high. Still the small sample size does not allow definitive conclusions on transportation mobility issues, but it was considered that these results warrant a reliable estimation of mobile emissions on a coarse grid of the Juarez basin. To polish the mobility forecasting capabilities of the model, further stages of research should approach a revision of the speed & capacity table values, if possible based on a Juarez specific speed/delay evaluation, as well as obtaining a more robust set of daily traffic counts.

Development of VMT and postprocessed speeds

The information previously described is of great value for system wide transportation evaluation and planning, from a stand point of mobility and accessibility. Yet, with minor dataview manipulation these by-link results are converted into daily vehicle-miles-of-travel (VMT) and postprocessed travel speeds for further mobile emissions modeling, which represents the final objective of this project.

Link VMT is obtained simply by multiplying the bi-directional link flow (vehicles/day) times the length of the link (in miles). For one-way links, speed is simply obtained by dividing distance over congested travel time (and multiplying the result by 60 to convert to mph). For two-way links speed is obtained separate for each direction of travel, and then the two are converted into one weighted speed, according to the proportion of flow on each direction.

As summary, Table 6 presents aggregate VMT and average postprocessed speeds by link type (functional classification), as well as the system wide totals. The average postprocessed speeds are weighted by the links VMT.

Table 6. Summary of VMT and average postprocessed speeds by link type.

		VMT	KVV*	% of total	(VMT)x(ppspeed)	Avg ppspeed** (mph)	Avg ppspeed (kph)
Functional Classification	Conn (0)	324,821	522,637	9.0%	6,807,093	20.96	33.72
	Expy (3)	1,145,816	1,843,618	31.8%	36,239,692	31.63	50.89
	PartD (4)	1,006,178	1,618,941	27.9%	20,571,106	20.44	32.90
	PartU (5)	637,608	1,025,912	17.7%	12,565,270	19.71	31.71
	MartD (6)	25,019	40,256	0.7%	276,782	11.06	17.80
	MartU (7)	369,885	595,146	10.3%	6,441,321	17.41	28.02
	MartUnp (8)	88,408	142,249	2.5%	1,507,220	17.05	27.43
	Ramp (12)	8,875	14,281	0.2%	262,022	29.52	47.50
System wide:		**3,606,611**	**5,803,038**		**84,670,506**	**23.48**	**37.77**

Note * : Stands for Kilómetros-Vehículo de Viaje (vehicle-kilometers of travel)

Note ** : Avg ppspeed by category = Σ [(VMT)x(ppspeed)] / Σ VMT

As seen here, by 1996 Juarez generated 3,606,611 VMT per day from AUTO generic mode, which corroborates previous estimations by TTI; in addition, transit operation on the base year generated daily around 103,000 VMT. Thus motorized trips generated over 3.7 million VMT per day during 1996.

These results spatially disaggregated can now be fed to the mobile emissions part of the project.

Appendix A

Desire-lines by specific sectors of Juarez (base year 1996)

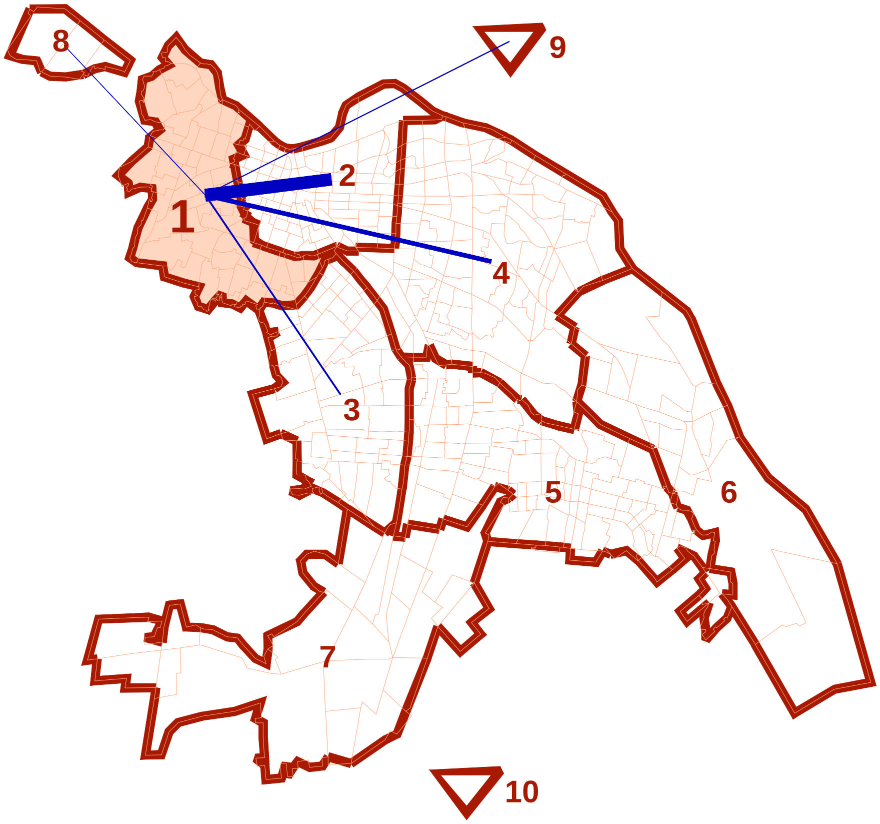

Figure A1. Desire-lines to and from sector 1. Flows <1000 veh/day not shown.

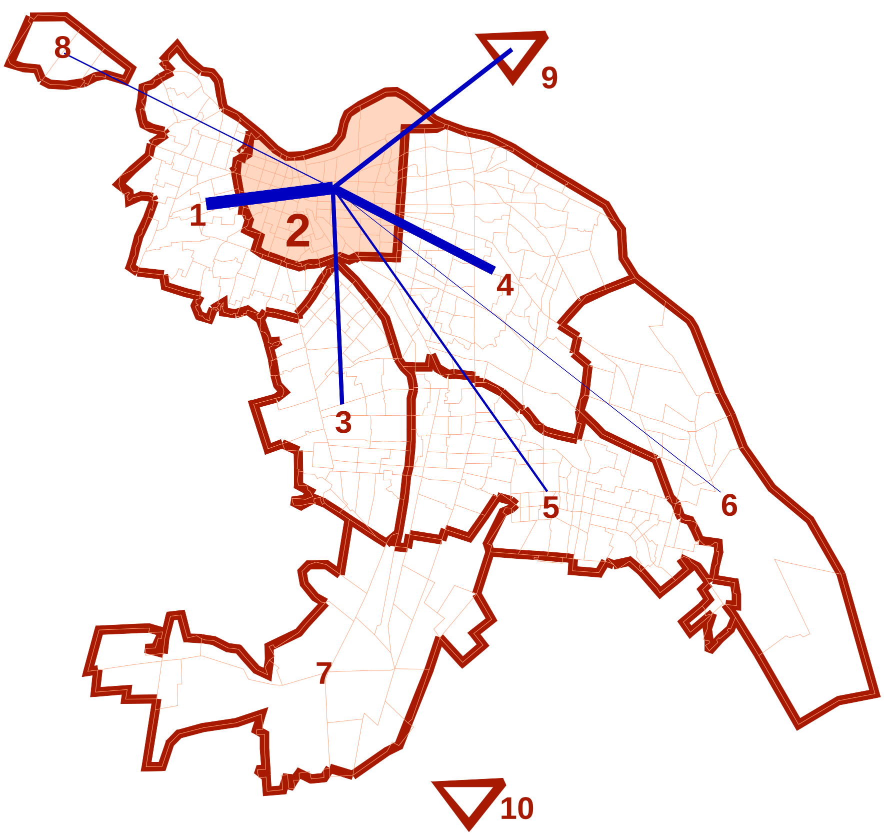

Figure A2. Desire-lines to and from sector 2. Flows <1000 veh/day not shown.

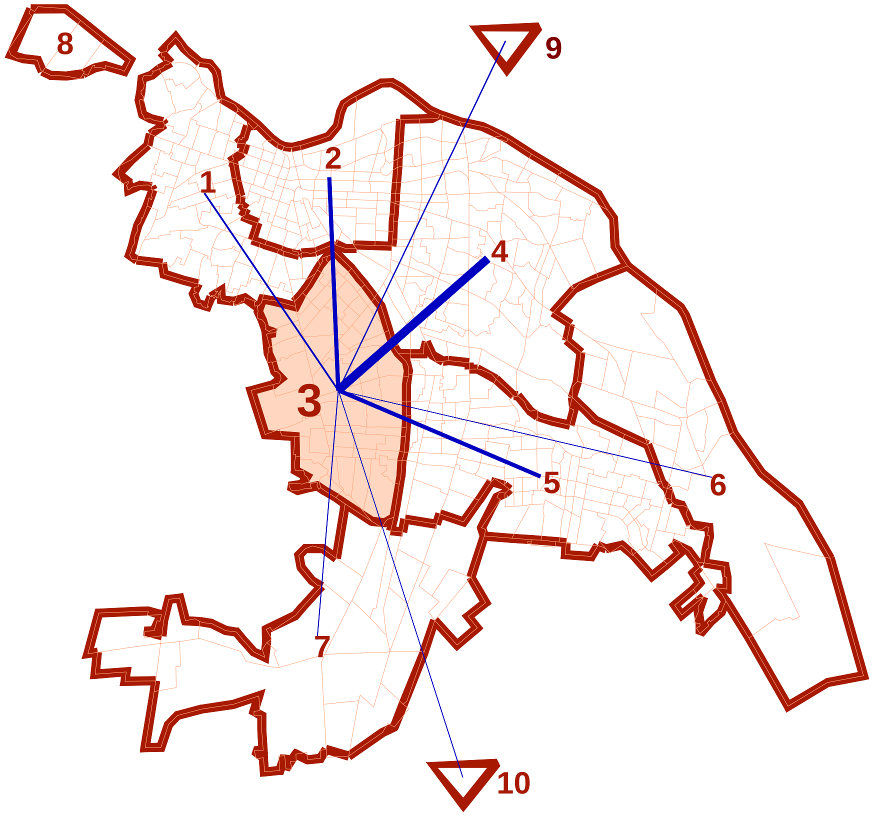

Figure A3. Desire-lines to and from sector 3. Flows <1000 veh/day not shown.

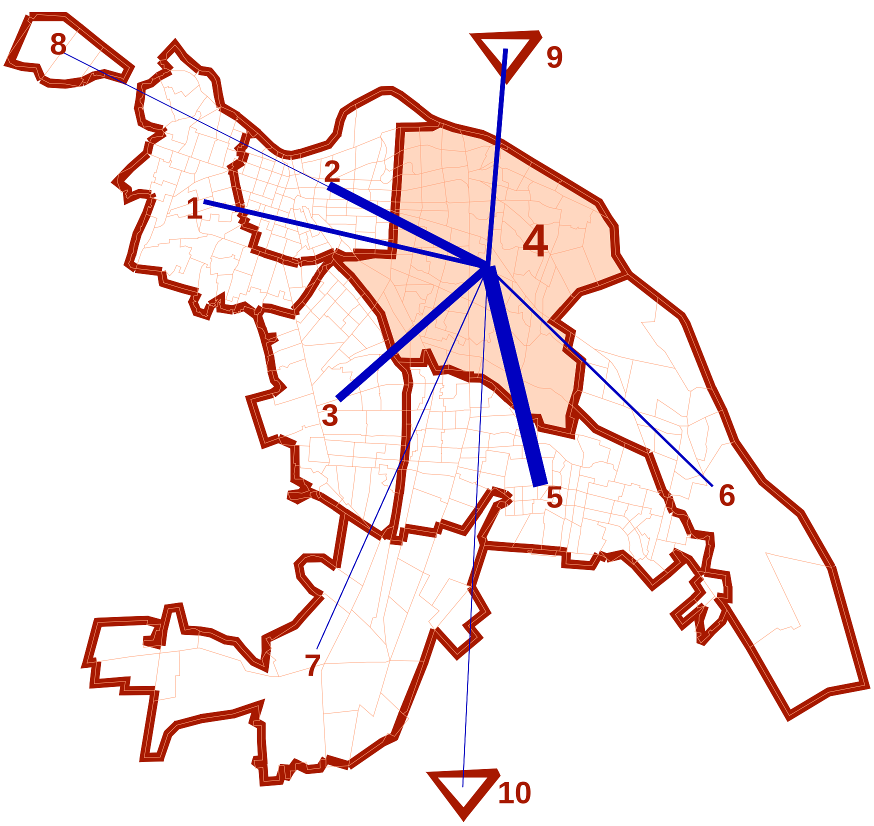

Figure A4. Desire-lines to and from sector 4. Flows <1000 veh/day not shown.

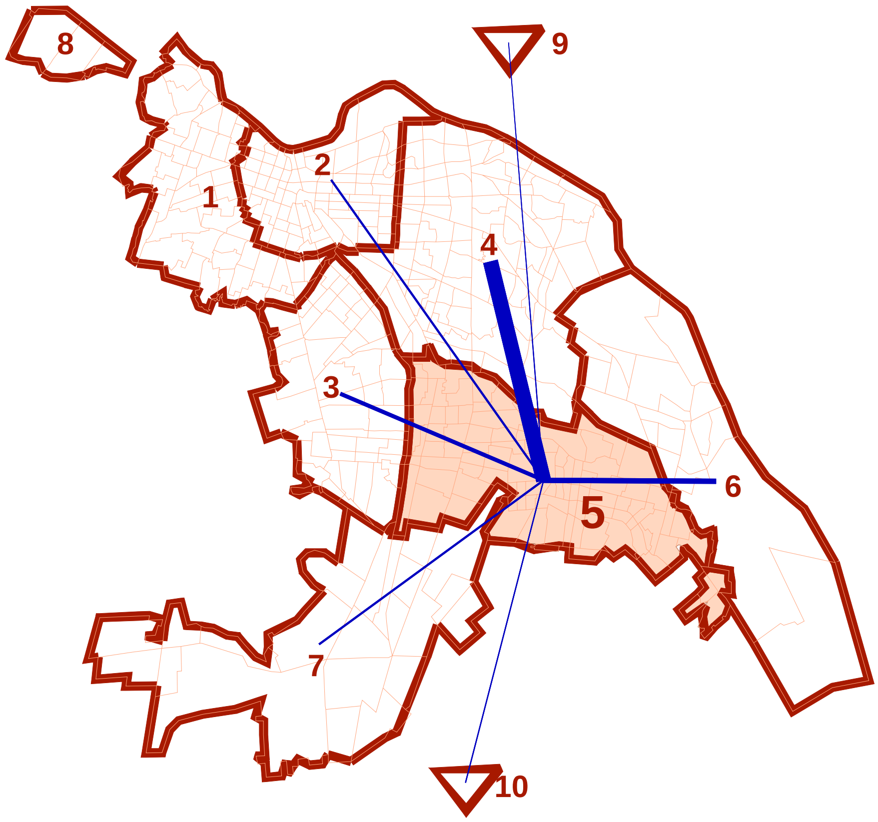

Figure A5. Desire-lines to and from sector 5. Flows <1000 veh/day not shown.

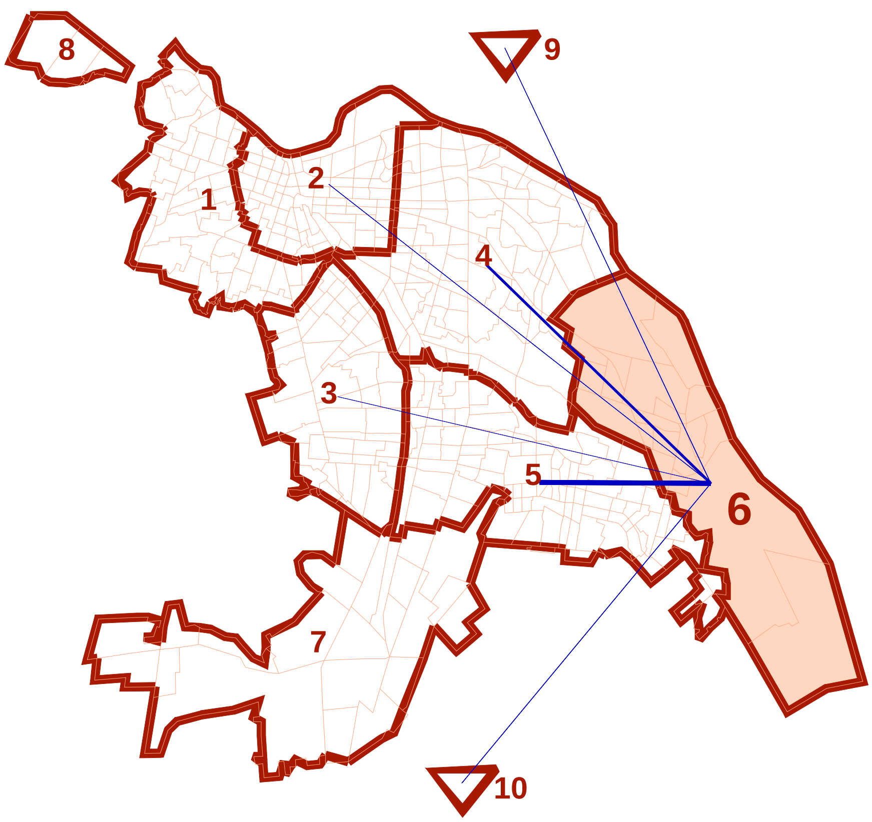

Figure A6. Desire-lines to and from sector 6. Flows <1000 veh/day not shown.

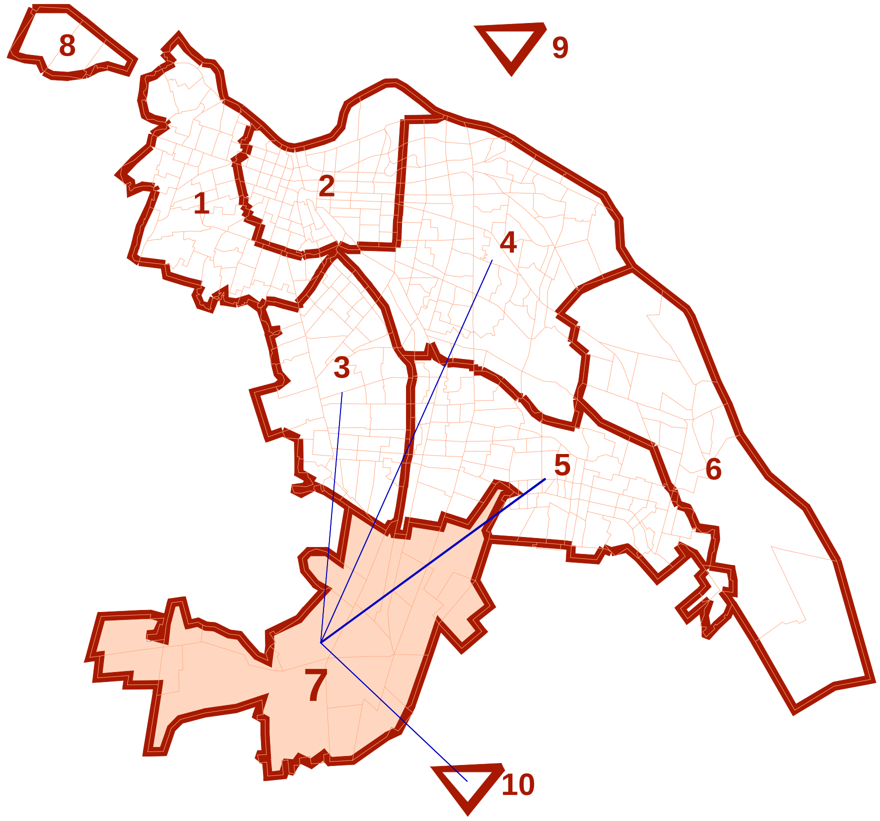

Figure A7. Desire-lines to and from sector 7. Flows <1000 veh/day not shown.

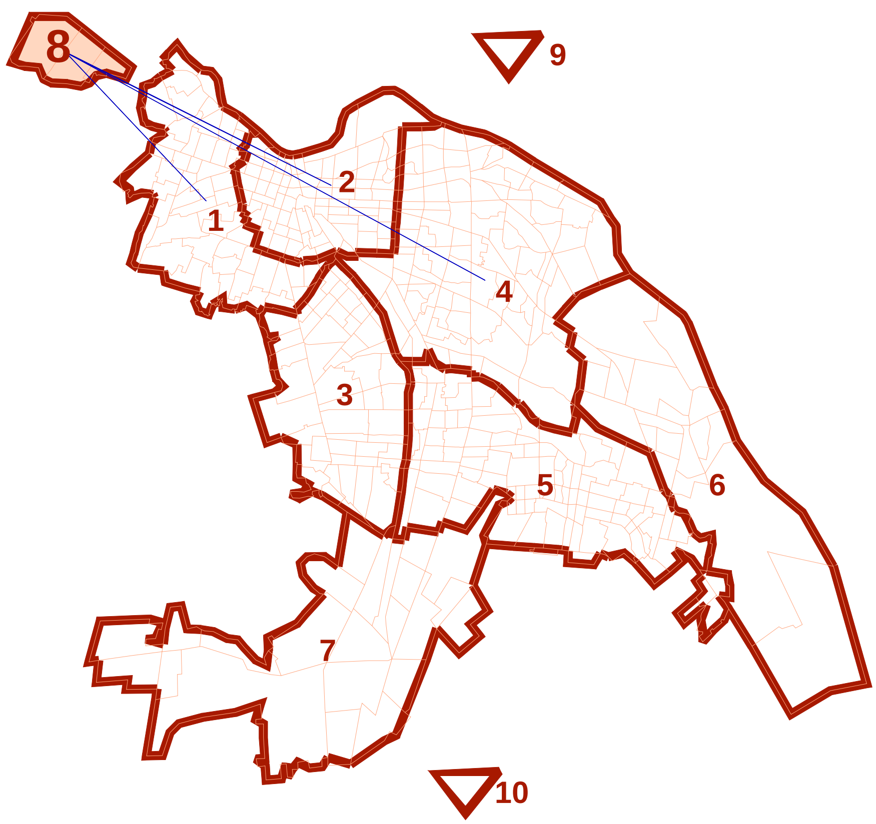

Figure A8. Desire-lines to and from sector 8. Flows <1000 veh/day not shown.

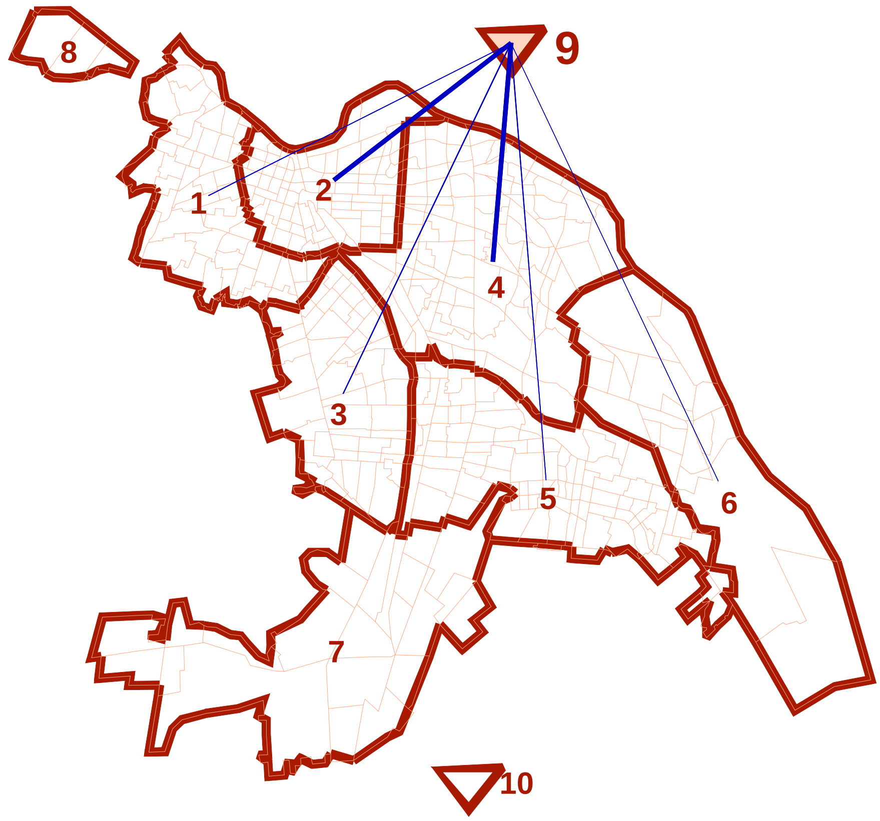

Figure A9. Desire-lines to and from sector 9. Flows <1000 veh/day not shown.

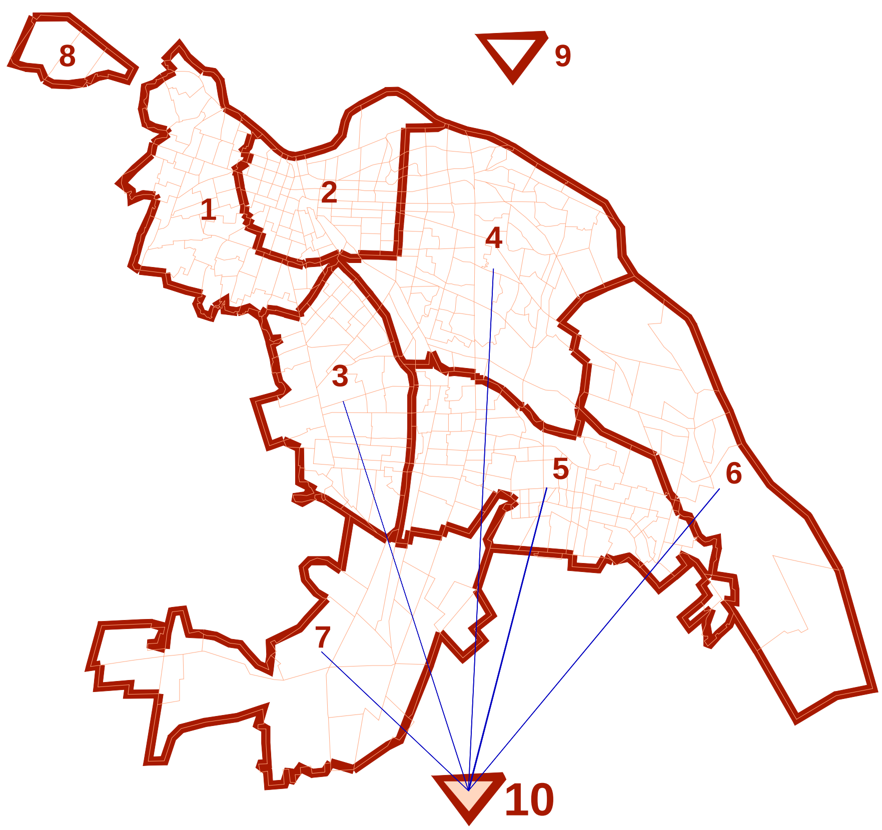

Figure A10. Desire-lines to and from sector 10. Flows <1000 veh/day not shown.