FINDINGS ON TRIP GENERATION HUBS IN ARGENTINA

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ABSTRACT

The Trip Generation Manual of the Institute of Transportation Engineers (ITE) has been traditionally used in Argentina to estimate trip rates and models for different Trip Generation Hubs (TGH). The proposed methodologies have been estimated using empirical data for North American conditions of modal split and traffic characteristics, therefore the limitations to its use in Argentina have remained largely unknown. Growing interest in land use planning and environmental impact assessment to protect urban quality of life led to research to better understand trip generation characteristics. Three trip purpose types have been addressed trough TGH in the city of Cordoba, selecting university centers as educational trip generators, hypermarkets as shopping trip generators, and hospitals as health centers. The purpose of this paper is to report on the findings. Since the studies were carried within the Ibero American TGH Research Network, results on car generation and modal person trips are also compared with other regional countries available cases.

Key words: Transportation, Trip Generation, Urban Mobility, Argentina

1. INTRODUCTION

In Argentina, traditional trip generation data is collected through Home based Origin-Destination Surveys, but growing interest in land use planning and environmental impact assessment to protect urban quality of life led to research to better understand characteristics of Trip Generation Hubs (TGH).These places or facilities of many different types are located in the cities clustering activities serving an important population at a scale producing significant number of trips and causing potential impacts on transportation and land use. Shopping Centers, Hypermarkets, Universities, Hospitals, Public Transportation Stations are just a few type of TGH (Portugal and Goldner, 2003).

To estimate car trip generation for particular projects of TGH, the Trip Generation Publications of the Institute of Transportation Engineers (ITE) have been traditionally used in Argentina, although knowing that the proposed trip rates and models are based on data reflecting North American socioeconomic and cultural characteristics that differ from local environment. The importance of the effects that TGH have on accessibility, performance of urban mobility and its interaction with land use development in Latin American cities raised the common problem of scarce local studies with funding shortages for research and led in 2005 to the creation of the Ibero American Trip Generation Hub Research Network, reaching participation of twenty eight Universities in nine countries. (Portugal et al, 2010).

The mobility conditions and its impact in quality of life in Argentinean cities are deteriorating with rapid growth of motorization aggravating congestion problems, road accidents and motor vehicles pollution. The aim of sustainable cities needs the support of a sustainable transportation pattern adapted to a broad guaranteed accessibility to all places for all citizens in safe and affordable ways. The city of Cordoba, with 1,3 million habitants is the second larger in Argentina after the megacity of Buenos Aires with 12 million. Although new large scale urban projects are required in all big cities to assess traffic impacts as part of environmental impact studies, it was almost unavailable the local characterization of most types of TGH and the limitations to the use of ITE methodologies remained largely unknown. Besides the impact studies addressed mainly car trip generation, lacking the person trip generation approach, involving transit and walking trips. The importance of this approach not only for new projects but for travel demand management in operating TGH was ignored or inapplicable due to lack of data. In that context a research team of the University of Cordoba joined the Ibero American Trip Generation Hub Research Network to better understand local travel behavior from the TGH side in a synergic research environment.

Among the different types of TGH, interest was primary directed to University Centers as study trip generation hubs since 11 % of the population of Cordoba are university students, to hypermarkets as shopping trip generation hubs because its impact on cluster formation in new food supply chain and to Health Centers due to its social importance for low income levels citizens. The main characteristics of the transportation pattern of the city of Cordoba can be drawn from the 2009 OD Transportation Survey (PTUBA, 2009). On a workday there are 2,36 million person trips in the city of which 36,9% are individual motorized (auto, taxi, motorcycle), 33,2% are massive motorized (bus, trolleybus, school minibuses) and 29,9 % are non motorized (pedestrian, bicycles).The trip rate per habitant older than 4 years is 1,84, with 74,7 % of people travelling and 25,3 % not travelling. Home based trips for study, shopping and health account for 22, 8 % (roughly 45% counting return to home) and modal split are presented in Table 1.

Table 1: Percentage and Modal split of study, shopping and heath daily trips.

Trip Motive	% of all trips	% Individual Motorized	% Massive Motorized	% Non motorized
Study	15.93	28.3	30.9	40.8
Shopping	5.03	17.2	23.4	59.5

2. EDUCATIONAL TRIP GENERATION HUBS

Education in Argentina involves 11,9 million of students (30% of total population) in mandatory levels including kindergarten (1 year), elementary school (6 years), and high school (6 years), and in optional tertiary and university education (3 to 6 years). There are Public Institutions where education is free of tuition in all levels, including universities, and there are also Private Institutions with varying fees according to the level.

The structure of the Educational Centers in the city of Cordoba is shown in Table 2, proportional to its size, except for the great number of university students which raise the share of students to 38% of city population.

Table 2: Structure of Educational Centers in the City of Cordoba

Level	Institutions	% Public	Teachers	Students
Kindergarten	412	70,8	3.040	45.914
Primary school	393	69,7	10.057	145.637
High school	265	47,2	19.329	120.846
Tertiary	83	24,0	4.267	40.209
Total without Universities	1.153		36.693	352.606
Universities	6 (2 public)	83% of students		138.000

Study trips are destination fixed, hyper frequent and peaking usually with city traffic and transit morning peaks. In Cordoba study trips are the motive of 85% of children trips (4 to 12 years old), 70% of teen trips (13 to 18 years old) and 24% of youth trips (19 to 30 years old) (PTUBA,2009)

Children in primary public schools are assigned to the nearest institution to their home, which means generally no more than 10 blocks, allowing walking trips. All levels of students regardless the type of institution applies in Cordoba to free pass in public transportation. Private minibuses operate on door to door monthly contracts mainly for kindergarten and primary private school students, and there are also many "kiss and drop" and "parent carpool" trips. Students in High school increase the use of transit, and university students add driving car and motorcycle alternatives. The university centers with buildings located in urban areas are important TGH because understanding the characteristics of the trips generated by students may allow solving travel flows toward urban environmental improvement.

The city of Cordoba was found particularly appropriate to study University TGH, with 105.000 students at the 400 years old Universidad Nacional de Cordoba (UNC), and 33.000 students in other 5 Universities, with buildings spread in CBD, a close neighborhood Ciudad Universitaria and four campuses in the periphery of the city.

Thirteen University Centers (UC) were selected for study (Herz, Galarraga and Pastor, 2009); two in CBD (School of Law and Faculty of Architecture, UNC), ten in Ciudad

Universitaria (9 Schools and Faculties UNC and the National Technological University) and one in the periphery (Catholic University of Cordoba).The dimensions of TGH range 3.000 to 50.800 m2 total built area; 1.480 to 13.000 m2 classroom area; 270 to 1370 faculty and staff. No correlation was found between enrolled students and the other dimensions due to differences in the type of careers offered. Field data was aimed to reveal the quantity and characteristics of person trips, travel modes and travel distance. Counts were performed on the number of people entering and leaving each UC in a normal academic day, and a questionnaire was administered to a sample of users of each UC. Total built area, classroom area, number of employees (faculty-staff), and registered students were tried as independent variables to predict person trips and car trips observed, resulting the students roll the best estimator.

Tables 3 presents the number of registered students of the 13 UC studied obtained from Universities files, the number of daily person trips attracted and produced obtained from counting persons at UC entrances, and the number of daily car trips attracted and produced counted directly in two cases (exclusive vehicle gates), and estimated from expansion of travel modes survey in the other cases, since parking lot entrances are not the only way to arrive by car. For example UC1 and UC 2 located downtown don´t have own parking.

Table 3: University Center (UC) data

University Center	Registered Students	Daily Person Trips	Daily Car Trips
1	3431	4392	496
2	9832	11376	853
3	5147	7212	1500
4	3158	3342	712
5	16610	26096	2296
6	5823	5976	1165
7	5374	6720	309
8	2970	3496	346
9	4705	5472	350
10	4289	5200	1300
11	1382	3144	720
12	10503	18494	4143
13	5200	9062	3253

Travel modes used were associated with distance of the UC to CBD, as shown in Table 4.

Table 4: Location of UC and modal choice

UC	Km to CBD	Car driver (%)	Car pas. (%)	Bus (%)	Walking (%)	Taxi (%)	Motor cycle (%)	Bicycle (%)
1	0	1,90	16,40	36,20	35,70	9,40	0,50	0,00
2	0	5,40	12,90	45,00	33,80	2,10	0,80	0,00
3	2	5,40	11,30	36,30	31,70	15,40	0,00	0,00
4	2	13,20	9,00	38,00	27,80	8,10	1,30	2,60
5	2	7,70	0,90	51,00	35,80	1,10	2,60	0,90
6	2	19,00	4,50	34,50	30,50	0,50	4,50	6,50
7	2	3,70	6,80	53,40	33,30	0,90	0,50	1,40
8	2	6,60	6,60	51,60	29,90	3,30	1,20	0,80
9	2	4,30	15,80	48,30	29,10	2,10	0,00	0,40
10	2	15,50	14,00	44,50	15,50	9,50	1,00	0,00
11	2	20,20	3,40	36,50	31,60	2,70	1,10	4,60
12	3	19,10	2,50	40,70	29,70	3,30	2,20	2,50
13	8	35,10	17,10	45,60	0,00	0.80	0.60	0.80

Population density in a radius of 1 km and 2 km was established from census data for each TGH and socioeconomic conditions of different TGH students were explored through available data of employment status and level of education attained by parents. As possible modal choice independent variables, population density resulted correlated with distance to CBD. Higher density housing supply is an attractor for students who are not from the city and must choose where to rent a house or apartment. Differences in socioeconomic conditions for the same distance to CBD didn´t explained modal split.

Isometrics and isochrones influence was analyzed with the trip information of districts of origin and mode of transport, measuring distances and travel times from the spatial distribution of trips to the UC. Figures 1 and 2 show that UC 13 (in the city periphery) has few trips shorter than 5 km or 15 minutes, while the UC near CBD accumulate up to 80% of trips within the 5 km isometric and 60% of trips within the 15 minute isochrone.

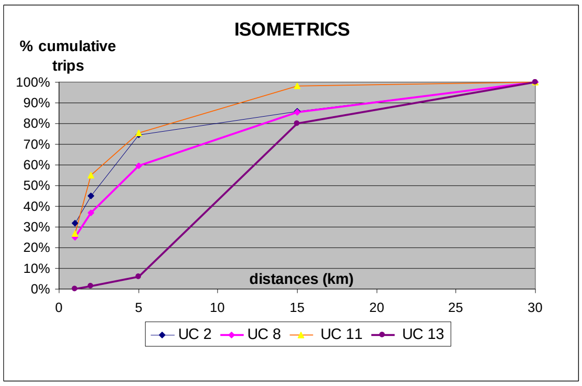

Figure 1: Cumulative trips in distances to UC

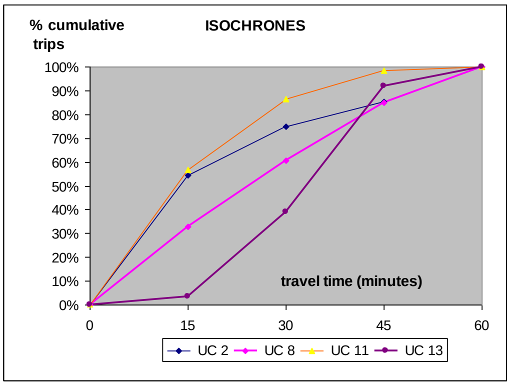

Figure 2: Cumulative trips in time to UC

2.1. Models for person trips

In developing the model for trip generation the dependent variable (Y) is the number of daily person trips generated by the UC (total person trips attracted and produced), and the independent variables that best fit is the number of students enrolled.

$$\text{Model Nº 1: } Y = a + b\,X1 \qquad (1)$$

Taking into account the large variations observed in modal choice for UC located far from CBD, it was decided to test a second model, considering a dummy variable that takes value zero (0) if the UC is located within 5 km from CBD and the value one (1) if the UC is farther from that distance.

$$\text{Model Nº 2: } Y = a + b\,X1 + c\,X2 \qquad (2)$$

Dependent variable: Y (number of daily person trips).
Independent variables: X1 (number of students enrolled at UC) ; X2 (dummy variable)

Table 5 shows the model type and the coefficients that resulted more certain for total daily trips (all modes), for individual motorized trips (car driver, car passenger, taxi, motorcycle), for bus trips, and walking and bicycling.

Table 5: Person trips, academic day

Case	Model	Coefficient a		Coefficient b		Coefficient c		R^2
		Value	t	Value	t	Value	t	
All modes	Nº 1	- 1224	- 1,37	1,61	13,0	NA	NA	0,94
Individual motorized	Nº 2	531	1,15	0,22	3,49	3181	3,44	0,63
Massive motorized	Nº 1	-1041	-2,23	0,80	12,33	NA	NA	0,93
Non motorized	Nº 2	- 816	- 2,33	0,59	12,40	- 2180	- 3,11	0,93

The number of students enrolled and the distance from the UC to CBD resulted main explanatory factors for the TGH. For total trips and transit trips is sufficient to consider the number of students, but to travel by car or walk is influenced remarkably by urban structure. A great part of nonresident students rent places at neighborhoods near CBD and Ciudad Universitaria, supporting a high share of pedestrian mode, proximity phenomenon that is not found in UC located in the City periphery

2.2. Models and rates for vehicle trips

To model vehicle trips the same independent variables used for person trips were tested, resulting best fitted model type Nº 2, as shown in equation 3, with the t statistics for each coefficient.

$$\underset{(0,74)}{Y = 173} + \underset{(2,63)}{0,17\,X1} + \underset{(2,40)}{2220\,X2} \qquad (R^2=0,54) \qquad (3)$$

Where.: Y : number of daily vehicle trips
X1: number of students enrolled at UC
X2 : dummy variable (1 if UC > 5 km from CBD; 0 otherwise)

The average vehicle trip rates per student, per day and per peak hour are shown in Table 6.

Table 6: Vehicle trip rates

Average vehicle trip ends per student enrolled at UC, weekday (Y1)			Average vehicle trip ends per student enrolled at UC, peak hour of generator (Y2)		
Mean	Range	Std. Dev.	Mean	Range	Std .Dev.
0,40	0,04-0,63	0,18	0,032	0,006-0,066	0,024

2.3. Comparison with other countries

Studies in the U.S.A. are reported by ITE for Universities and Colleges under Land Use 550 (Institutional) only for vehicle trips, for different temporal dimensions, using as independent variables either Number of Students or Number of Employees. There is no information on person trips and modal split. Table 7 shows two types of trip rates analogous to the types shown in Table 6 from the Cordoba Study, with the values reported in the last 2 editions of ITE Trip Generation. It can be observed that vehicle generation rates have slightly decreased in the U.S.A., but they are much larger than vehicle trips per students found in Argentinean Universities.

Table 7: Average rates for vehicle trip ends. Universities.

Registered Student Base (X)	Daily car generation rate (Y1)			Peak hour at UC car generation rate (Y2)		
	Mean	Range	Std. Dev.	Mean	Range	Std. Dev.
USA (ITE,2008)	2,37	2,03-2,67	1,56	0,20	0,15-0.,30	0,45
USA (ITE,2012)	1,71	1,25-3,31	1,39	0,17	0,09-0,26	0,41
Argentina (Herz et al 2009)	0,40	0,04-0,63	0,18	0,032	0,006-0,066	0,024

In the Ibero-American Trip Generation Hub Study Network were developed comparisons among available information (Jacques, M. A. P. et al 2010a). In Brazil, Souza (2007) reports for University Centers car trips rates based in registered students at UC by shift, attracted at the beginning and produced at the end, which added results in mean of 1,18 and range from 0,67 to 1,65. Person trips are split 51,7% by car, 33,1 % by bus, 6,5% walking and 8,7% other.

Difficulties in characterizing Educational Institution trip generation at all levels are treated with a proposal of a new methodology in Jacques M A P. et al (2010b)

3. COMMERCIAL TRIP GENERATION HUBS

Most frequent shopping trips are related to food and household item needs. In Argentinean cities the food supply chain is shared between neighborhood shops, minimarkets, supermarkets and hypermarkets. Daily purchases at greengroceries, butcheries, bakeries, grocery stores and delicatessen explain the high share of non motorized shopping trips, reaching in the city of Cordoba almost a 60 % as shown earlier in Table 1. In Cordoba, shopping is the trip purpose of 10% to 12 % of all trips for people under 65 years old, and 30% of trips for older citizens (PTUBA,2009)

The entry of hypermarkets in larger Argentinean cities in the 90´s started a shift in frequency and mode of transportation of shopping trips, with predominance of car trips and peaks on weekends. The possibility of hypermarkets to retail al lower prices due to high volume throughput raised concern about the effect on small neighborhood business and about traffic impacts in the location area, promoting the need to better understand the trip generation characteristics of this foreign business format in the local environment. Four hypermarket chains operating in Argentina have stores in Cordoba: Carrefour, Wal-Mart, Libertad, and Dinosaurio.

An initial study was conducted in the city of Córdoba, involving seven Hypermarket TGH corresponding to three different chains (Galarraga et al.,2007). Hypermarkets considered were selected from different city environments, covering ranges of total built area between 5,500 and 23,600 m2, of sale areas between 3,000 and 11,000 m2 and checkout lines between 32 and 63 . These three characteristics were considered as candidate independent variables for potential trip generation models

To characterize the temporal activity of Hypermarkets as TGH, information was obtained from yearly sale tickets statistics of some local Hypermarkets. Aggregated data is shown in Tables 8 to 10. Table 8 shows that higher activities are at evening hours, while Table 9 shows that weekends and Friday are the most trip attraction days, and that monthly seasonality is moderate with December as the month with highest trip attractions.

Table N 8 - Distribution of the number of operations for different hours of the week

Hour	Monday to Thursday (%)	Friday (%)	Saturday (%)	Sunday (%)
9:00 to 16:00	38,7	36,8	42,1	42,8
16:00	6,7	6,7	8,1	7,2
17:00	8,3	7,4	8,8	8,9
18:00	9,3	9,4	8,3	9,4
19:00	12,0	10,7	9,5	10,5
20:00	12,2	12,8	8,7	10,3
21:00	10,1	11,7	9,3	7,8
22:00	2,7	4,5	5,3	3,1
Total	100	100	100	100

Table 9 Distribution of number of operations by day of the week and by month

Weekly operations (%)		Monthly Operations (%)	
		January	8,1
		February	7,6
		March	8,0
		April	8,0
		May	8,4
Monday	9,8	June	9,0
Tuesday	10,6	July	8,9
Wednesday	10,0	August	8,1
Thursday	10,6	September	7.7
Friday	13,4	October	8,2
Saturday	26,5	November	7,6
Sunday	19,2	December	10,4
Total	100	Total	100

Data was collected by counts of vehicles entering and exiting the gates, and interviews with customers leaving the checkpoint lines at late afternoon and evening hours. Table 10 shows information referred to automobile trips ends (sum of attracted and produced) recorded from 17 to 20 hours on Fridays and Saturdays, and trip counts in the peak hour.

Table 10 – Total trip ends by car (attracted and produced) from 17:00 to 20:00 hours

Hypermarket	Friday		Saturday	
	3 hour period	Peak Hour	3 hour period	Peak Hour
H1	2.275	895	3.739	1.322
H2	1.672	658	2.696	954
H3	3.665	1.441	6.107	2.160
H4	2.072	815	3.402	1.203
H5	839	330	1.356	480
H6	679	267	1.102	390
H7	1.587	624	2.587	915

Questionnaires to a sample of customers (family group) leaving the checkout lanes in all Hypermarkets provided data on the modal split of trips, trip lengths and type of trip in the case of cars, whether specific round trip from home (primary), diverted from other destination or passing to other destination. This characterization is use by ITE (2008) since shopping trips are not mandatory destination as work or study trips, and the impact in the urban network is null for passing trips, marginal for diverted trips and full for primary trips. Table 11 shows modal split of customers trips.

Table 11 - Modal split of trips to hypermarkets in percentage

Hypermarket	Car (%)	Taxi (%)	Bus (%)	Walking (%)	Other (%)
H 1	73,9	5,0	9,1	9,0	3,0
H 2	70,6	3,4	8,1	13,0	4,9
H 3	80,4	5,3	5,8	4,0	4,5
H 4	58,2	6,2	2,2	26,4	7,0
H 5	71,3	5,9	2,9	15,5	4,4
H 6	55,6	8,6	8,6	20,0	7,2
H 7	77,4	9,2	1,7	8,3	3,4
Average	69,6	6,2	5,5	13,7	4,9

Adding cars plus taxis, individual motorized modes involve near 76% of trips to hypermarkets in Cordoba, a much higher than the 17,2% estimated from OD Home surveys for all shopping trips in the city, according to earlier cited Table 1. Studies in other countries of the region for similar size hypermarkets, show similar shares. For example Silva (2006) found in Brazilian cities averages of 74% individual motorized, 15% walking, 4% by bus and the rest for other modes. While modal split for hypermarket trips are seldom reported in USA studies, car trips are 96% or more (Brehmer and Butorac, 2003).

Regarding the trip length distribution, customer addresses samples were obtained from the questionnaires, and each Hypermarket was divided in zones with isometric lines drawn with radii of 1, 2, 3 and 4 km determining five zones of influence: the first zone closest to the hypermarket with a total area of 3.1 km^2, the second zone between 1 and 2 km from the TGH covering an area of 9.5 km^2 ; with the third occupying 15.7 km^2 ; the fourth with an area of 22 km^2; the fifth zone covering from 4 km to city borders, and a sixth zone for trips originated outside the city. Table 12 presents the proportion of travel with clients located in each of the zones of influence.

Table 12 - Distribution of customers according to the areas of origin of travel

Hypermarket	Zone 1 (%)	Zone 2 (%)	Zone 3 (%)	Zone 4 (%)	Zone 5 (%)	Zone 6 (outside city borders)
H 1	14	12	11	10	31	21
H 2	8	15	19	8	35	15
H 3	18	20	11	9	24	18
H 4	16	32	17	13	14	8
H 5	22	27	12	10	22	7
H 6	27	29	21	5	12	6
H 7	22	24	12	10	26	6
Average trips (%)	18	23	15	9	23	12
Average Trip length (km)	0,7	1,7	2,7	3,7	8,0	36,0

Trips longer than 4 km (zones 5 and 6) account from 18 to 50% and trips less than 1 km account from 8 to 27% of all trips.

By observing the modal split percentages shown in Table 11 and the distribution of customers by proximity to the TGH shown in Table 12, appears a clear trend to interpret that modal split varies with trip length. Table 13 shows the modal shares grouped by zones. As it would be expected, the areas closer to the hypermarket have higher percentage of non motorized trips (walking and bicycles) and lower percentage of motorized trips (automobiles and buses).

Table 13 - Modal Distribution by Zone Groups

Zone	Car (%)	Taxi (%)	Buses (%)	Walking (%)	Bicycles (%)
1	43,9	5,1	1,4	46,0	3,6
2, 3 e 4	60,6	14,3	7,8	9,7	7,6
5 e 6	82,9	3,1	10,9	0,0	3,1

For car trips, the questionnaire inquired the type of trip, whether primary, diverted or passing. Table 14 shows that, on average, almost 83% of car trips to hypermarkets are made specifically as round trips.

Table 14 - Type of car trips

Hypermarket	Trip home-hypermarket-home		
	Yes	No	
	Primary trips (%)	Diverted trips (%)	Passing Trips (%)
H1	74,8	12,1	13,1
H2	94,4	3,5	2,1
H3	81,6	11,2	7,2
H4	78,4	14,4	7,2
H5	78,5	11,4	10,1
H6	84,0	11,3	4,7
H7	86,6	7,1	6,3
Average	82,6	10,1	7,2

Relating type of trips with trip length, Table 15 shows that the longer the trip the higher the proportion of diverted and passing trips.

Table 15 - Distribution of trips by category according to the zone.

Zone	Primary trips (%)	Diverted trips (%)	Passing trips (%)
1	92,4	5,7	1,9
2, 3 e 4	83,7	9,0	7,3
5 e 6	70,4	16,9	12,7

3.1. Models and rates for vehicle trips

Models and rates for car travel, considering Fridays and Saturdays peak hours were estimated. Friday peak shows the most unfavorable condition for adjacent street traffic and Saturday peak shows the highest TGH rate.

Through linear regression, trip generation models were estimated considering as dependent variable (y) the total number of generated vehicle trips (sum of produced and attracted trips) during peak hours. These models were estimated for three different independent variables (x): a) the total built area - GFA, expressed in m2 b) the total sales area - GLA, in m2, c) the number of checkout lines. The following models were obtained.

$y = a\,x + b$ (3)

$\mathrm{Ln}\,y = \mathrm{Ln}\,a + b\,x$ (4)

Tables 16 and 17 present the models with better statistical adjustment for Fridays Saturdays and days respectively.

Table 16 - Model generation for peak hour. Day: Friday.

Variable	Model	R^2	Coefficient t
GFA (m^2)	Ln y = 0,9224 Ln x – 2,447	0,56	2,52
GLA (m^2)	Ln y = 1,0681 Ln x – 3,001	0,71	3,51
Checkout lines (Nº)	y = 36,1403 x – 861,30	0,85	5,32

Table 17 - Model generation for peak hour. Day: Saturday

Variable	Model	R^2	Coefficient t
GFA (m^2)	Ln y = 0,9351 Ln x – 2,185	0,56	2,50
GLA (m^2)	Ln y = 1,0799 Ln x – 2,750	0,71	3,46
Checkout lines (Nº)	Y = 54,5072 x – 1322,27	0,85	5,31

While the number of checkout lines is the best explanatory independent variable, followed by the total sale area, the total built area is the more suited variable for planning purposes (eg. issuing land use permissions for the TGH), since different layouts may be developed inside the building. This is the criteria adopted to estimate vehicle trips generation for Shopping Centers in Sao Paulo, Brazil (Pereira G, 2011).

Table 18 reports the values of average rates of generation, the standard deviation and the minimum and maximum rates for both peak hours as of Friday to Saturday. These results are associated with the sum of produced and attracted trips (inbound and outbound) at hypermarket.

Table 18 – Average rates for vehicle trip ends, peak hour Friday and Saturday

Variable	Friday			Saturday		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
GFA (m^2)	0,0435	0,0150	0,0217-0,0609	0,0640	0,0225	0,0316-0,0913
GLA (m^2)	0,0924	0,0320	0,0643-0,1488	0,1362	0,0487	0,0943-0,2230
Checkout lines (Nº)	15,6270	5,5747	7,2174-22,8796	23,0212	8,4319	10,5339-34,2843

3.2. Comparison with other countries

In the Ibero-American Trip Generation Hub Study Network were developed comparisons among available information (Galarraga et al, 2011a). Related to travel pattern, Brehmer and Butorac (2003), Silva (2006) Galarraga et al. (2007) provide information about the modal split and trip types to hypermarkets, as shown in Tables 19 and 20.

Table 19 - Modal split. Hypermarkets.

Study	Car	Bus	Walking	Others
USA: Brehmer Butorac (2003)	96%	0,6%	0,4%	1%
Brazil: Silva (2006)	74%	4%	15%	7%
Argentina: Galarraga et al. (2007)	76%	5%	14%	5%

Table 20- Trip types. Hypermarkets.

Study	Primary trips	Diverted trips	Passing trips
USA: Brehmer and Butorac (2003)	52%	24%	24%
Brazil: Silva (2006)	74%	13%	13%
Argentina: Galarraga et al. (2007)	83%	10%	7%

A comprehensive study of hypermarkets trip generation reported by Pearson et al (2009) in the USA found an average of 26% pass-by trips at weekday peak period. This trend may be related to longer trip lengths.

Studies in the U.S.A. are reported by ITE for Hypermarkets under Land Use 813 (Free Standing Discount Superstore; Retail) only for vehicle trips, for different temporal dimensions, using as independent variable the Gross Floor Area (GFA). There is no information on person trips and modal split. Table 21 shows PM peak hour average rates for vehicle trip ends for Friday and Saturday, with the values reported in the last 2 editions of ITE Trip Generation. It can be observed that vehicle generation rates in the U.S.A. are stable, and they are very similar to vehicle trips per GFA found in Argentinean Hypermarkets.

Table 21: Average rates for vehicles trip ends. Hypermarkets.

GFA (m^2)	PM peak hour Friday			PM peak hour Saturday		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
USA (ITE,2008)	0,0504	0,0258	0,0287-0,0798	0,0608	0,0281	0,0322-0,0858
USA (ITE,2012)	0,0474	0,0255	0,0221-0,0798	0,0608	0,0281	0,0322-0,0858
Argentina Galarraga et al. (2007)	0,0435	0,0150	0,0217-0,0609	0,0640	0,0225	0,0316-0,0913

4. HEALTH CENTERS TRIP GENERATION HUBS

Health care in Argentina is free of charge in Public Hospitals and covered by mutual funds, prepaid services or direct payment in Private Hospitals. Taking the city of Cordoba as example, trips related to health care are not significant in the share of motives (less than 2% shown in earlier Table 1), but accessibility to Hospitals is a major social issue for its impact in older citizens and low income persons. Health trips accounts from 2 to 4% of trip motive for persons under 65 years old, but raise to 14 % of trip motive for people over 65 (PTUBA, 2009)

Hospitals were studied in Córdoba as TGH to better understand trip characteristics. Research developed by Albrieu et al. (2009) and Albrieu, Pastor, Galarraga (2011) analyzed seven hospitals, six public and one private. Three of the public hospitals are clustered in an area situated near downtown in a sector with significant institutional buildings and the bus terminal station. The other hospitals studied are situated in various districts of the city.

This study performed two thousand and seven hundred user surveys on access to hospitals. Field surveys were conducted for the morning peak hours on working days. The study period was from 7:30 to 9:30. Besides the surveys were counted the people and vehicles that came in and out of hospitals and parking areas, both inside and on the street.

Tables 22 presents the characteristics of the different Health Centers (HC) under study

Table 22: Health Center (HC) data

Heath Center	Type of HC	Number of Beds	Number of MD	Total Built Area (m2)
1	Public	230	206	21100
2	Public	101	143	7513
3	Public	170	302	12886
4	Public	86	130	9849
5	Public	121	250	15013
6	Public	79	48	11739
7	Private	266	450	22000

To characterize hospital users, it was decided to study the location of the homes of patients and visitors attending the hospital, using as an indicator the percentage of households with Unmet Basic Needs (UBN). This indicator allows identifying areas of different socio economic characteristics and purchasing power.

Trip origin neighborhoods were grouped in different categories, considering the percentage of households with at least one indicator of UBN. Category 1 between 0 and 5%, category 2 between 6 and 10%, category 3 between 11 and 20%, category 4 between 20 and 30% and category 5 over 30%. Category 3 corresponds to the city average values, categories 1 and 2 to neighborhoods with better social and economic situation, category 4 to neighborhoods with low socioeconomic status and category 5 to extremely poor neighborhoods.

Table 23 shows the percentages of patients in each category who attend to public and private hospitals. It reports that 95% of patients in the private hospital comes from zones 1 and 2, while the largest percentage of patients presenting to a public hospital live in zones 2 and 3 (62%). Moreover the most disadvantaged neighborhoods inhabiting Category 5 do not use the private hospital. The 42% of patients seen at the public hospital come from neighborhoods in the categories 3, 4 and 5, while only 5% of patients in the private hospital correspond to these categories.

Table 23 : Percentage of patients in each category

Type of HC	Category				
	1	2	3	4	5
Public	19%	38%	24%	13%	5%
Private	56%	39%	2%	3%	0%

Table 24 shows modal split considering the type of hospital (public or private)

Table 24: Modal split for HC

Type of HC	Car	Bus	Taxi	Motor cycle	Bicycle	Walking
Public	24	44	15	5	2	10
Private	61	12	17	0	2	8

It can be observed that the higher proportions of trips are made by bus in the public hospitals (44%), but in the case of the private hospital the higher proportions of trips are made by car (61%).

4.1. Rates for person trips

Rates were calculated per person trip generation (produced plus attracted trips) considering the following explanatory variables: number of beds, number of medical doctors and total built area (1000 m^2). These rates were estimated for walking trips, by car (private car plus taxi) and by bus, both for public and private hospitals. See Table 25

Table 25: Rates for person trips

Variable	Type of HC	Walking	Car + Taxi	Bus
Number of Beds	Public	0,417	1,607	2,108
	Private	0,354	3,261	0,510
Number of Medical doctors	Public	0,304	1,172	1,538
	Private	0,209	1,927	0,302
Total built area (1000 m^2)	Public	4,199	16,196	21,246
	Private	4,283	39,424	6,172

In all cases, the higher trip generation rate is by car for the private hospital, while the higher trip generation rate is by bus for public hospitals.

4.2. Rates for vehicle trips

Assuming an average occupancy rate of 1.4 persons / vehicle for private cars and taxis, Table 26 shows the obtained rates for vehicle trips.

Table 26: Rates for vehicle trips

Type of HC	Number of Beds	Number of Medical doctors	Total built area (1000 m^2)
Public	1,148	0,837	11,568
Private	2,329	1,377	28,160

The main conclusion is that in general, trip generation of individual vehicles in private hospitals is twice as high as in public hospitals. Nevertheless this conclusion is limited and cannot be generalized at this stage, since only one private hospital was analyzed.

4.3. Comparison with other countries

Within the Ibero-American Trip Generation Hub Study Network different research results were compared (Galarraga et al, 2011b). Related to travel pattern, Carqueja, H. L. (2006) and Gontijo et Raia Jr (2010), provide information about the modal split to hospitals, as shown in Table 27.

Table 27: Modal split. Hospitals.

Study	Type of HC	Car	Bus	Taxi	Walking	Others
Brazil: Carqueja, H. L. (2006)	Public	56	31	2	4	7
	Private	47	44	2	3	4
Brazil: Gontijo and Raia Jr (2010)	Public	55	29	--	6	10
Argentina: Albrieu et al. (2011)	Public	24	44	15	10	7
	Private	61	12	17	8	2

Studies in the U.S.A. are reported by ITE for Hospitals under Land Use 610 only for vehicle trips, for different temporal dimensions, using as independent variable the Number of Beds and the total built area (GFA). There is no information on person trips and modal split. Table 28 shows AM peak hour average rates for vehicle trip ends, with the values reported in the last 2 editions of ITE Trip Generation, and a study reported from Venezuela.

Table 28: Average rates for vehicles trip ends. Hospitals.

A.M. Peak Hour of Generator	Number of beds	GFA (1000m^2)
USA (ITE,2008)	1,24	13,47
USA (ITE,2012)	1,45	10,35
Argentina: Albrieu et al. (2011) Public	1,15	11,57
Argentina: Albrieu et al. (2011) Private	2,33	28,16
Venezuela (Rosas and Sananez, 2010) Private	5,00	22,15

It can be seen that average hourly rates are similar in USA and in Argentinean Public Hospitals, but in the case of private hospitals, both in Argentina and Venezuela, show higher rates than reported for USA.

5. CONCLUSIONS AND RECOMMENDATIONS

Attracted and produced person trips and modal split were specifically addressed to account for individual motorized, massive motorized and non motorized modes at educational, shopping and health Trip Generator Hubs. Spatial and temporal dimensions were defined for traffic counts, person counts and user interviews at the different TGH types. Thirteen public and private University Centers ranging from 1300 to 16000 students were surveyed at weekday hours. Seven hypermarkets ranging from 5500 to 23600 m2 were surveyed on Fridays and Saturdays evening peak hours. Seven public and private Hospitals ranging from 80 to 270 beds were surveyed at morning peak hours.

Regression models for car trip generation and trip rates for person car trips, bus trips and pedestrian trips were estimated, using particular considerations for each TGH type. Car trip generation predictions were compared with ITE`s models and rates, showing some agreement for hypermarkets and hospitals but relevant differences for university centers.

The analysis indicates that local characteristics of trip generation at commercial, educational and health centers, especially the modal split, influences the car generation rates. Transit availability and locations within walking distances reduce individual motorized split share, with noticeable potential for transportation management.

Due to the effort to obtain field data it is difficult, at the local level, to cover the great diversity of TGH treated in Trip Generation (ITE, 2012) with data intensive collection. The Ibero American Trip Generation Hub Study Network has helped to overcome the limitations creating a framework to encourage local efforts in the region with the possibility to share methodologies and results.

According to the impact that great trip generators have on land use policy and urban mobility it is recommended to give TGH priority in research needs for sustainable development of our cities.

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REFERENCES

Albrieu,M. L.;Pastor,G.;Galarraga,J. (2011) Análisis comparativo de viajes a hospitales públicos y privados.:XXV Congresso de Pesquisa e Ensino em Transportes, Anais ANPET, BeloHorizonte, Brasil

Albrieu, M. L ;Pastor, G.;Depiante,V.;Maldonado,P; Molfino,A. (2009) Características de los viajes a polos sanitarios de la ciudad de Córdoba – Argentina. Anales del XV Congreso Latinoamericano de Transporte Público- CLATPU, Buenos Aires, Argentina.

Brehmer, C. L.; Butorac, M. A. (2003). Trip Generation Characteristics of Discount Supermarkets. ITE Journal Vol. 73 N° 11., Washington D.C., U.S.A

Carqueja, H. L. (2006) Estudo da Geração de Viagens e de Parâmetros para o Dimensionamento de Estacionamento e Meio-Fio para Hospitais na Grande Florianópolis. Universidade Federal de Santa Catarina , Florianopolis, Brasil

Galarraga, J.; Herz, M.; Albrieu, L.; Depiante, V. e Pastor, G. (2007) Características de los Viajes en Hipermercados de la Ciudad de Córdoba - Argentina. XIV CLATPU Congreso Latinoamericano de Transporte Público y Urbano, Rio de Janeiro, Brasil

Galarraga J, Herz M, Raia A, (2011a) Cadernos: Polos Geradores de Viagens Orientados à Qualidade de Vida e Ambiental – Hipermercados", http://rtedpgv.coppe.ufrj.br .

Galarraga J, Herz M, Albrieu L, Raia A, da Silva, G, Sanánez J G, Rosas, A. (2011b) Cadernos: Polos Geradores de Viagens Orientados à Qualidade de Vida e Ambiental – Hospitais", http://rtedpgv.coppe.ufrj.br .

Gontijo, G. A. S.; Raia A. Jr. (2010). Caracterização das viagens atraídas pelo PGV/hospital Santa Casa de Misericórdia de São Carlos/Brasil. Anais do IV Congresso Luso Brasileiro para o Planejamento Urbano, Regional, Integrado e Sustentável, Faro, Portugal.

Herz, M., Galarraga J., Pastor G. (2009). Características de Generación y Distribución Modal de Viajes en centros Educativos Universitarios. XV CLATPU Congreso Latinoamericano de Transporte Público y Urbano, Buenos Aires, Argentina.

ITE – Institute of Transportation Engineers (2008). Trip Generation, 8th Edition, Washington,D.C., U.S.A.

ITE – Institute of Transportation Engineers (2012). Trip Generation Manual, 9th Edition, Washington,D.C., U.S.A.

Jacques M A P, Bertazzo A, Galarraga J, Herz M (2010a) Cadernos: Polos Geradores de Viagens Orientados à Qualidade de Vida e Ambiental – Estabelecimentos de Ensino", http://rtedpgv.coppe.ufrj.br .

Jacques M A P, Bertazzo A, Galarraga J, Herz M (2010b) Nova Abordagem para o estudo das viagens geradas nas instituições de ensino. Transportes v XVIII n 1 p 75-85., Brasil

Pearson, D. F., Bochner, B. S., Ellis P.; Ojah, M. I. (2009). Discount Superstore Trip Generation. ITE Journal Vol. 79 N° 6., Wahington. D.C., U.S.A.

Pereira Glaucia (2011) Modelo de atracao de automoveis por shopping Center. Boletin Tecnico 46. CET, Sao Paulo, Brasil

Portugal, L.S. and Goldner (2003). Estudo de Polos Geradores de Viagens e de seus Impactos nos Sistemas Viários e de Transportes. Ed. Edgard Blucher, Sao Paulo, Brasil

Portugal,L.S, Florez J, da Silva A.N.R.(2010) Latin American Transportation Research Network: a tool for transforming and upgrading the sustainable mobility and the quality of life. 12th WCTR, Lisboa, Portugal

PTUBA (2009), EOD-Encuesta Origen Destino 2009- Movilidad en el Área Metropolitana de Córdoba, Secretaría de Transporte de la Nación, Buenos Aires, Argentina

Rosas, A.M.; Sananez,J.C. (2010) Estimación de Tasas de Generación de Viajes para Hospitales Distrito Metropolitano de Caracas. Anais do XXIV Congresso de Pesquisa e Ensino em Transportes, ANPET,Salvador, Brasil.

Silva, L. R.; Silva, P. C. M. (2006). Modelos de geração de viagens endoexógenos para pólos geradores de viagens – Estudo de caso nos supermercados e hipermercados. XX ANPET – Congresso de Pesquisa e Ensino em Transportes. Brasília, Brasil.

Souza S. C. F (2007). Modelos para Estimativa de Viagens Geradas por Instituições de Ensino Superior. Dissertação de Mestrado, PublicaçãoT.DM-009A/2007, Departamento de Engenharia Civil e Ambiental, Faculdade de Tecnologia. Universidade de Brasília, Brasil