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DESIGN MODELS FOR THE INTEGRATION OF ROADWAY TRANSPORTATION SYSTEMS INTO THE CITY'S PLANNING

Walid AL-SHAAR
Beirut, Lebanon
Mobile phone: +96170271243

ABSTRACT: *During the phase of preparation of new masterplan, urban planners have no scientific tool/criteria to calculate and to find the optimum value of road network area. The aim of this paper is to identify a calculation basis (design models), to be used during the design of new masterplans, and during the assessment of the road network in any city/town based on transportation demands (trip generation in the area).A new vision in urban planning can be represented by indicating the volume over capacity ratio (V/C), for each section of the roadway network in each LandUse, by identifying the mathematical proportionality of road surfaces, relatively to LandUse areas and population, relating these 3 factors based on the V/C ratio required, depending on trip generation rates and landUse types.These models can be identified by establishing mathematical models analogously related to the "Distribution of neurons in Mammalian Neocortex".*

KEYWORDS: Models, Road, Land, Land Use;

INTRODUCTION

During the phase of the preparation of new master plan, urban planners don't have any scientific tool/criteria to calculate and find the optimum road network area to be distributed all over the master plan Land Use areas. Generally, urban planners state clearly that the percentage of road network area to the total land area in any new master plan should not exceed 30 to 35 % (as stated by many urban planners in Lebanese engineering consulting companies).The absence of such design models may lead to make the master plan not optimistically feasible and sometimes not feasible at all. Nowadays, the checking design process of roads system in any new master plan, consists of using the following checkpoints (as stated by transportation planners in different consulting engineering companies in Lebanon):

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- Assessing the level of service in each road section independently,
- Relating road sections to a fixed (present and future) population size and a fixed LandUse size

This research identifies a calculation basis (design mathematical models) to calculate the optimum road network area to be used during the design of new master plan, and during the assessment of the road network in any city/town based on transportation demands (trip generation in the area).

N.B: Not taking into consideration any unexpected future urban development may present a big transportation planning issue.

Objectives

The aim of the research is:

- To identify a calculation basis (design models) to be used during the design of new master plan or during the assessment of the road network in any city/town based on transportation demands (trip generation in the area).
- To make any new urban master plan much more feasible by calculating the optimized road network area based on the design and the selected V/C ratio.
- To recommend the setup of new urban development legislation decrees, stating that the road network established for any new master plan (based on the design models), should present a reference for the capacity of the city/town in terms of the evolution and the growth of population, and in terms of urban expansion, where the concept here is to state that each resident, or any person entering the city (workers, employees, students…), should have an allocated space share of the road.

In addition and based on establishing an optimum road network, it is also recommended to set an urban expansion standard in collaboration with local authorities, and using law enforcement in order to keep the roadway system in track with the city growth.

Coordination with authorities (municipalities…) should periodically be held, in order to keep the population density, its uniformity, and the vertical/horizontal shape of the city in conformance with the master plan design.

- To identify the mathematical proportionality of road surfaces, population to the LandUse areas, relating these 3 factors based on V/C required ratio depending on trip generation rates and land use types.

Hypotheses

The following hypotheses motivated the research plan:

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- Unplanned/Unlimited Urban expansions in the city, with non-respect to infrastructure road networks, may cause the oversaturation in cities in terms of services (road queuing times and delays…), infrastructures, natural resources, socio-economic conditions and environmental negative impacts.
- Not identifying the capacity of road network, and not setting a legislated plan for any urban expansion in term of population growth or any vertical/horizontal LandUse expansion, will lead to an uncontrollable urban evolution in the said city.
- An increase in the number of highways and motorways users may cause uncontrollable road and traffic management.
- City road network systems may be operated by similar principles as the Neocortex. Neurons are conduits for information-related signals on which brain computations rely, highways are conduits for physical materials and people. But from the perspective of the city as a whole, the materials and people that roads transport are crucial to the large-scale function provided by the city, and are, in a sense, signals—that one signal is electric and the other physical may not matter in regards to the fundamental principles governing them. In addition to the prima facie analogy between city highway networks and the brain's neural connections, there are several other reasons we chose to examine city highway networks *(1).*

METHODOLOGY

CHANGIZI and DESTEFANO in 2009 (1) stated that the total surface area of highways would appear to be of interest, and the neocortical analog of this is the cumulative surface area of white matter axons. Total white matter surface area is the product of the number of neurons, the length of white matter axons, and the axon diameter. Assuming axon length scales as the cube root of white matter volume, one may derive that the total surface area of white matter axons scales as the 1.375 power of total convoluted surface area. The total highway surface area may similarly be estimated, and assuming highway length scales as the square root of city land area, one may derive that total highway surface area scales as the 1.433 power of city land area, close to the 11/8 exponent for the analogous quantity in Neocortex.

Population scales as the 1.205 power of road (not highway) surface area for a set of 29 German cities *(CHANGIZI and DESTEFANO, 2009)*

Figure 1 depicts a comparison of City Highway System and Neocortex Exponents for Quantities as a Function of Surface Area.

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Stage 1: Design Models Concept

These design models, can be identified by establishing mathematical models analogously related to the "Distribution of neurons in Mammalian Neocortex" by trying to identify the best parameters values, to fit the road network area required for different LandUse types.

This means defining a formulae combining the road network area to the LandUse area by using proportionality factors α, β.

Moreover, a population- LandUse surface area relation, is also be established by using a proportionality coefficient Δ *(Ref: Eng. Walid-AL-SHAAR)*

In this research, it is considered that road network surface area (instead of highway) may be estimated to be scaled as the 1.433 power of city land area, close to the 11/8 exponent for the analogous quantity in Neocortex.

Stage 2: Elaborated Design Models

The basis formulas to be used in the study are depicted below:

1- $\mathbf{A = \alpha \times S^{1.433}}$ (A: represents the road network areas instead of Highway surface area)
(Ref: Eng. Walid-AL-SHAAR)

It is the formulae combining:

- The road network area "A" (Area in square miles) to
- The LandUse area "S" (Area in square miles)
- α is the Proportionality Factor to be calculated, it is relating A to S

2- $\mathbf{P = ß \times A^{1.205}}$ *(1)*

It is the formulae combining:

- The road network area "A" (Area in square miles) to
- The LandUse population "P"
- β is the Proportionality Factor to be calculated, it is relating A to P

3- $\mathbf{P = \Delta \times S^{1.727}}$ (based on relating the above 2 formulas and eliminating the element "A")
(Ref: Eng. Walid-AL-SHAAR)

It is the formulae combining:

- The LandUse area "S" (Area in square miles) to
- The LandUse population "P"
- Δ is the Proportionality Factor to be calculated, it is relating P to S

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Stage 3: Calculation of Proportionality Factors α, β and Δ

The third stage of this research is to establish the 5 scenarios for Land use road network in terms of the ratio of road Volume to Capacity (V/C) to be taken 25%, 40%, 50% and 75% (and 100% only for residential areas), then to determine the coefficient Alfa and Beta to fit the criteria of these ratios.

A base condition is taken in this study, where the traffic is considered to be constituted only by passenger car vehicles with dimensions as indicated below:

"The term 'one space' used in the standards refers to standing area only and the recommended minimum dimensions for a car space are 4.8 meters by 2.4 meters." *(2)*

A- V/C = 25% means that for each car, it should be a free space reservation area equal to 3 car spaces (free space reservation = 3 x 4.8 = 14.4 m/lane) in addition to the car space.

B- V/C = 40% means that for each car, it should be a free space reservation area equal to 1.5 car spaces (free space reservation = 1.5 x 4.8 = 7.2 m/lane) in addition to the car space.

C- V/C = 50% means that for each car, it should be a free space reservation area equal to 1 car space (free space reservation = 1 x 4.8 = 4.8 m/lane) in addition to the car space.

D- V/C = 75% means that for each car, it should be a free space reservation area equal to 0.33 car spaces (free space reservation = 0.33 x 4.8 = 1.58 m/lane) in addition to the car space.

E- V/C = 100% means that for each car, there is no additional free space reservation

Table 1: Free and total space reservation for different V/C: volume to capacity ratios

V/C (%)	**Length of one passenger car (m/Lane)**	**free space reservation for each passenger car (m/Lane)**	**Total reservation for each passenger car (m/Lane)**
25	4.8	14.4	19.2
40	4.8	7.2	12
50	4.8	4.8	9.6
75	4.8	1.58	6.38
100	4.8	0	4.8

Source: Eng. Walid AL-SHAAR

For each LandUse area, the number of vehicles (trip generated in the land use) are calculated based on the ITE manual *(3)* which could guide us to set the road surface area required to serve each type of land use trip generations at different above selected volume to capacity ratios.

To be noted that the study shows for each alternative of volume to capacity (V/C) ratio, 3 base

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conditions of lane widths (commonly known/used lane widths): 3.0 m, 3.3 m and 3.6 m to be taken into consideration during the calculation phase.

Table 2: Trip generation rates for different LandUse as per ITE manual 9th edition (3)

<table>
<tr><th>N°</th><th>LandUse Type</th><th>LandUse selection from ITE manual</th><th>Reference</th></tr>
<tr><td rowspan="2">1</td><td>"Industrial Park Areas"</td><td>The trip generation model for Industrial Park Areas is the model using the "Average Vehicle Trip Ends vs 1000 Sq. Feet Gross Floor Area" on a "weekday – peak hour of adjacent street traffic, one hour between 7 and 9 am" since the industrial areas in Tripoli are characterized by a mix of manufacturing, service and warehouse facilities with a wide variation in the proportion of each type of use from one location to another.</td><td>ITE 9th Edition - Volume 2 - Page 146</td></tr>
<tr><td colspan="3">Industrial Park
(130)
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 7 and 9 a.m.
Number of Studies: 43
Average 1000 Sq. Feet GFA: 427
Directional Distribution: 82% entering, 18% exiting
Trip Generation per 1000 Sq. Feet Gross Floor Area
Average Rate: 0.82 | Range of Rates: 0.12 - 2.28 | Standard Deviation: 1.02</td></tr>
<tr><td rowspan="2">2</td><td>"Recreational "</td><td>The trip generation model for Recreational Areas is the model using the "Average Vehicle Trip Ends vs 1000 Sq. Feet Gross Floor Area" on a "weekday –peak hour of adjacent street traffic, one hour between 4 and 6 pm " since the Recreational areas in Tripoli are characterized by letting the community join the recreational and cultural activities.</td><td>ITE 9th Edition - Volume 2 - Page 960</td></tr>
<tr><td colspan="3">Recreational Community Center
(495)
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.
Number of Studies: 7
Average 1000 Sq. Feet GFA: 72
Directional Distribution: 49% entering, 51% exiting
Trip Generation per 1000 Sq. Feet Gross Floor Area
Average Rate: 2.74 | Range of Rates: 1.05 - 5.37 | Standard Deviation: 2.32</td></tr>
</table>

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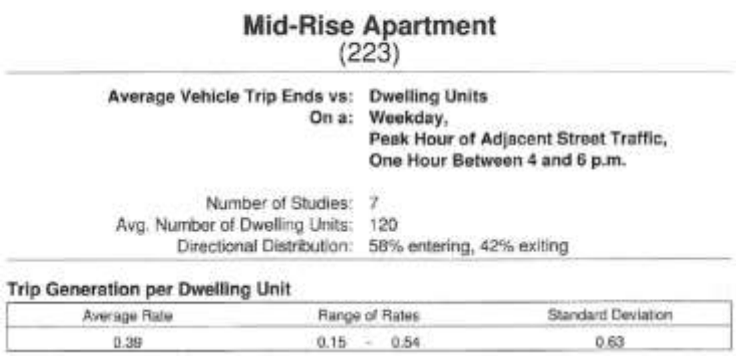
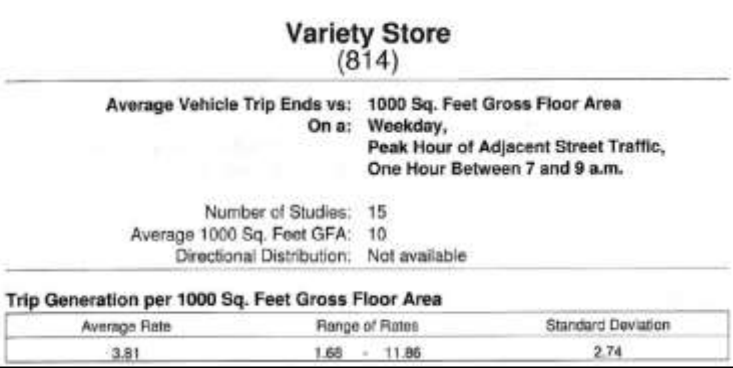
<table>
<tr><th>N°</th><th>LandUse Type</th><th>LandUse selection from ITE manual</th><th>Reference</th></tr>
<tr><td></td><td colspan="3"></td></tr>
<tr><td rowspan="2">3</td><td>“Residential”</td><td>The trip generation model for Residential Areas is the model using the “Average Vehicle Trip Ends vs Dwelling Units” on a “weekday – peak hour of adjacent street traffic, one hour between 4 and 6 pm” since the residential areas in Tripoli are characterized by mid-rise apartments located in buildings with 3 to 10 floors .</td><td>ITE 9th Edition - Volume 2 - Page 388</td></tr>
<tr><td colspan="3">
Mid-Rise Apartment
(223)
Average Vehicle Trip Ends vs: Dwelling Units
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.
Number of Studies: 7
Avg. Number of Dwelling Units: 120
Directional Distribution: 58% entering, 42% exiting
Trip Generation per Dwelling Unit
Average Rate: 0.39 · Range of Rates: 0.15 - 0.54 · Standard Deviation: 0.63</td></tr>
<tr><td rowspan="2">4</td><td>“Commercial/Retail: Variety Store”</td><td>The trip generation model for Variety Store Areas is the model using the “Average Vehicle Trip Ends vs 1000 Sq. Feet Gross Floor Area” on a “weekday – peak hour of adjacent street traffic, one hour between 7 and 9 am” since the scheme of Commercial/Retail areas in Tripoli are characterized by the Variety commercial Stores.</td><td>ITE 9th Edition - Volume 3 - Page 1451</td></tr>
<tr><td colspan="3">
Variety Store
(814)
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 7 and 9 a.m.
Number of Studies: 15
Average 1000 Sq. Feet GFA: 10
Directional Distribution: Not available
Trip Generation per 1000 Sq. Feet Gross Floor Area
Average Rate: 3.81 · Range of Rates: 1.68 - 11.86 · Standard Deviation: 2.74</td></tr>
</table>

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N°	LandUse Type	LandUse selection from ITE manual	Reference
5	" Educational: University-College"	The trip generation model for **University-College Areas** is the model using the "*Average Vehicle Trip Ends vs **Students***" on a "***weekday – peak hour of adjacent street traffic, one hour between 7 and 9 am***".	ITE 9th Edition - Volume 3 - Page 1077
	University/College (550) **Average Vehicle Trip Ends vs: Students** **On a: Weekday,** **Peak Hour of Adjacent Street Traffic,** **One Hour Between 7 and 9 a.m.** Number of Studies: 8 Average Number of Students: 13,372 Directional Distribution: 78% entering, 22% exiting **Trip Generation per Student** Average Rate: 0.17 / Range of Rates: 0.09 - 0.26 / Standard Deviation: 0.41		
6	" Educational: High School"	The trip generation model for **High School Areas** is the model using the "*Average Vehicle Trip Ends vs **1000 Sq. Feet Gross Floor Area***" on a "***weekday – P.M peak hour of Generator***".	ITE 9th Edition - Volume 3 - Page 1024

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N°	LandUse Type	LandUse selection from ITE manual	Reference
		High School (530) **Average Vehicle Trip Ends vs:** **1000 Sq. Feet Gross Floor Area** **On a:** **Weekday,** **P.M. Peak Hour of Generator** Number of Studies: 44 Average 1000 Sq. Feet GFA: 194 Directional Distribution: 31% entering, 69% exiting **Trip Generation per 1000 Sq. Feet Gross Floor Area** Average Rate: 2.12 — Range of Rates: 0.98 - 5.14 — Standard Deviation: 1.74	
7	" Educational: Elementary School"	The trip generation model for **Elementary School Areas** is the model using the "*Average Vehicle Trip Ends vs **1000 Sq. Feet Gross Floor Area***" on a "***weekday – peak hour of adjacent street traffic, one hour between 4 and 6 pm***".	ITE 9th Edition - Volume 3 - Page 989
		Elementary School (520) **Average Vehicle Trip Ends vs:** **1000 Sq. Feet Gross Floor Area** **On a:** **Weekday,** **Peak Hour of Adjacent Street Traffic,** **One Hour Between 4 and 6 p.m.** Number of Studies: 10 Average 1000 Sq. Feet GFA: 84 Directional Distribution: 45% entering, 55% exiting **Trip Generation per 1000 Sq. Feet Gross Floor Area** Average Rate: 1.21 — Range of Rates: 0.79 - 2.25 — Standard Deviation: 1.20	

Source: ITE trip Generation manual 9th Edition

CALCULATION PROCEDURES

5.1. First Design Model relating Road network area and the LandUse area

The calculation for the interrelation coefficients α, of LandUse area and the related required road network area, will take place for the LandUse types within the indicated range of units as indicated in the table below, based on trip generation rates provided by the ITE Manual and the following

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the formulae:

A= α x S1.433

Where

A: Road network area in the related LandUse (areas in square miles)

S: LandUse area (areas in square miles)

α: Proportionality Coefficient

Table 3: LandUse types and the range of units used in the study

LandUse type	Range of units in the study (1000 Sq. Feet)	Reason for this Selection of the Range of units in the study
Industrial Park	140 – 10,000	The range of units is selected since it is commonly known that the minimum area could be considered 140,000 sq. feet and the maximum would not exceed 10,000,000 sq. feet
Recreational areas	140 – 10,000	
Commercial areas	140 – 10,000	
High school area	140 – 10,000	
Elementary school area	140 – 10,000	

Source: Eng. Walid AL-SHAAR

N.B: It is to notice that during the calculation, the used trip generation rates are:

a. The minimum values of trip rates indicated by ITE manual *(3)*

b. The maximum values of trip rates indicated by ITE manual, if the percentage of calculated required road does not exceed 35%, otherwise the maximum rate used is calculated based on this assumption (not exceeding the 35%) as the urban planners in Lebanon advise to not exceed this percentage.

Second Design Model relating Road network area and the LandUse Population

The calculation for the interrelation coefficients β, of Population and the related required road network area, will take place for the LandUse types within the indicated range of units as indicated in the table below, based on trip generation rates provided by the ITE Manual and the following the formulae:

P= β x A1.205

Where

P: Population in the LandUse

A: Road network area in the related LandUse (areas in square miles)

β: Proportionality Coefficient

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Table 4: LandUse types and their range of units used in the study

LandUse type	**Range of units in the study**	**Reason for this Selection of the Range of units in the study**
Residential areas	2,000 – 25,000 (Population)	Residential areas/compounds studies in this research are considered to have a capacity of a minimum 2,000 residents and the maximum 25,000 residents
University area/campus	140 – 10,000 (Students)	It is commonly known that one university building or one campus can provide the educational services for a minimum of 700 students and maximum 7,000 students except other special cases

Source: Eng. Walid AL-SHAAR

N.B: It is to notice that during the calculation, the used trip generation rates are:
a. The minimum values of trip rates indicated by ITE manual
b. The maximum values of trip rates indicated by ITE manual, if the percentage of calculated required road does not exceed 35%, otherwise the maximum rate used is calculated based on this assumption (not exceeding the 35%) as the urban planners in Lebanon advise to not exceed this percentage.

Third Design Model relating LandUse area and the LandUse Population

Limitations: This model should be applied only for residential zones.

The following considerations should be taken into account prior to start applying this mathematical model and finding the optimal proportionality factor Δ:

1- Observations and data collection to determine the average number of car parking basements* for all buildings in the study zone should first of all be done.

2- The space reserved in the basement for car parks and maneuvers = 52% of the LandUse flat area (based on common practice of architects in many engineering consulting companies in Lebanon)

3- The Area needed for one passenger car (parking area and the entry/exit maneuvers) = (5+ (5.5/2)) x 2.5) m^2 (see figure 2 below - Turning and parking space (Neufert 3rd edition))

4- Observations and data collection to determine the car ownership rate per capita in the study area.

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5- Observations and data collection to determine the average household size in the study area. Figure 2 shows Turning and parking space (Neufert 3rd edition (4))

In this article the study area was the “Tripoli” City in Lebanon.

- An assumption of the number of parking basements in residential area was made and it is considered that the number is equal to one.
- The car ownership = 434 cars for 1000 person in Lebanon in 2014 *(5)*
- The average household size = 5.21 person/house *(6)*

* parking basements flat area are considered equal to the building plot/parcel area.

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FINDINGS (RESULTS AND DISCUSSION)

These Design models represent a scientific tool/criteria to calculate and find the optimum road network area to be distributed all over the master plan.
These results and findings of proportionality factors when used, may lead to make the master plan optimistically feasible.

6.1 First Design Model proportionality factors (α)

Results depicted here are limited only for Industrial areas with V/C = 25% (because of numerous land Use types)

Table 5: Coefficient Alfa α in INDUSTRIAL AREAS with V/C = 25% and with minimum trip generation rates

Number of units in the study (1000 Sq. feet)	**Land use Area (mi2)**	**Min Trip generated at peak hour (during one hour)**	**V/C = 25% (Min trip generated)**			
			Required Road for Min trip generate (km/lane)	**Lane width**		
				3	**3.3**	**3.6**
				Coefficient α		
140	0.005	16.8	0.32	**0.736**	**0.810**	**0.883**
1,000	0.035	120	2.3	**0.314**	**0.345**	**0.377**
2,000	0.071	240	4.61	**0.232**	**0.256**	**0.279**
3,000	0.107	360	6.91	**0.195**	**0.214**	**0.234**
4,000	0.143	480	9.22	**0.172**	**0.189**	**0.206**
5,000	0.179	600	11.52	**0.156**	**0.172**	**0.187**
6,000	0.215	720	13.82	**0.144**	**0.159**	**0.173**
7,000	0.251	840	16.13	**0.135**	**0.148**	**0.162**
8,000	0.286	960	18.43	**0.127**	**0.140**	**0.153**
9,000	0.322	1080	20.74	**0.121**	**0.133**	**0.145**

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10,000	0.358	1200	23.04	**0.115**	**0.127**	**0.139**

Source: Eng. Walid AL-SHAAR

Table 6: Calculation of Coefficient Alfa α in INDUSTRIAL AREAS with V/C = 25% and with maximum accepted* trip generation rates

Number of units in the study (1000 Sq. feet)	**Land use Area (mi2)**	**Min generated Trip at peak hour (during one hour)**	**V/C = 25% (Max accepted* trip generation rate)**			
			Required Road for Min trip generated (km/lane)	**Lane width**		
				3	**3.3**	**3.6**
				Coefficient α		
140	0.00502	79.1	1.52	**3.467**	**3.813**	**4.160**
1,000	0.03587	565	10.85	**1.479**	**1.627**	**1.775**
2,000	0.07174	1130	21.7	**1.096**	**1.205**	**1.315**
3,000	0.10761	1695	32.54	**0.919**	**1.011**	**1.103**
4,000	0.14348	2260	43.39	**0.811**	**0.893**	**0.974**
5,000	0.17935	2825	54.24	**0.737**	**0.810**	**0.884**
6,000	0.215	3390	65.09	**0.681**	**0.749**	**0.817**
7,000	0.251	3955	75.94	**0.637**	**0.700**	**0.764**
8,000	0.286	4520	86.78	**0.601**	**0.661**	**0.721**
9,000	0.322	5085	97.63	**0.571**	**0.628**	**0.685**
10,000	0.358	5650	108.48	**0.546**	**0.600**	**0.655**

Source: Eng. Walid AL-SHAAR

* based on assumption that the total road network area should not exceed 35% of land use area

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(with roads lane width of 3.0 m)

Figures 3 and 4 show the variation of the value of Coefficient α in Industrial areas with 25% volume over capacity ratio and based respectively on minimum and maximum (accepted) rate of trip generation.

Second Design Model proportionality factors (β)

Results depicted here are limited only for residential areas with V/C = 25% (because of numerous land Use types)

Table 7: Calculation of Coefficient Beta β in RESIDENTIAL AREAS with V/C = 25% and with minimum trip generation rates

Number of residents	Number of Dwelling units in the study	Min Trip generated at peak hour (during one hour)	V/C = 25% (Min trip generated)			
			Required Road for Min trip generated (km/lane)	Lane width		
				3	3.3	3.6
				Coefficient β		
2,000	384	58	1.11	**1,174,271**	**1,046,864**	**942,660**
3,000	576	86	1.66	**1,080,611**	**963,366**	**867,473**
4,000	768	115	2.21	**1,018,725**	**908,195**	**817,794**
5,000	960	144	2.76	**973,174**	**867,586**	**781,227**
6,000	1,152	173	3.32	**937,472**	**835,757**	**752,567**
7,000	1,344	202	3.87	**908,310**	**809,760**	**729,157**
8,000	1,536	230	4.42	**883,784**	**787,894**	**709,468**
9,000	1,727	259	4.98	**862,700**	**769,098**	**692,542**
10,000	1,919	288	5.53	**844,266**	**752,664**	**677,745**
11,000	2,111	317	6.08	**827,931**	**738,101**	**664,631**
12,000	2,303	345	6.63	**813,293**	**725,052**	**652,881**
13,000	2,495	374	7.19	**800,057**	**713,252**	**642,255**
14,000	2,687	403	7.74	**787,994**	**702,498**	**632,572**

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15,000	2,879	432	8.29	**776,928**	**692,632**	**623,688**
16,000	3,071	461	8.84	**766,717**	**683,529**	**615,491**
17,000	3,263	489	9.4	**757,247**	**675,086**	**607,889**
18,000	3,455	518	9.95	**748,425**	**667,222**	**600,807**
19,000	3,647	547	10.5	**740,176**	**659,867**	**594,185**
20,000	3,839	576	11.06	**732,434**	**652,965**	**587,970**

Source: Eng. Walid AL-SHAAR

Table 8: Coefficient Beta β in RESIDENTIAL AREAS with V/C = 25% and with maximum trip generation rates

Number of residents	**Number of Dwelling units in the study**	**Min Trip generated at peak hour (during one hour)**	**V/C = 25% (Max trip generated)**			
			Required Road for Min trip generated (km/lane)	**Lane width**		
				3	**3.3**	**3.6**
				Coefficient β		
2,000	384	173	3.32	**312,491**	**278,586**	**250,856**
3,000	576	259	4.98	**287,567**	**256,366**	**230,847**
4,000	768	345	6.63	**271,098**	**241,684**	**217,627**
5,000	960	432	8.29	**258,976**	**230,877**	**207,896**
6,000	1,152	518	9.95	**249,475**	**222,407**	**200,269**
7,000	1,344	605	11.61	**241,715**	**215,489**	**194,039**
8,000	1,536	691	13.27	**235,188**	**209,670**	**188,800**
9,000	1,727	777	14.93	**229,577**	**204,668**	**184,296**
10,000	1,919	864	16.58	**224,672**	**200,295**	**180,358**
11,000	2,111	950	18.24	**220,325**	**196,420**	**176,868**
12,000	2,303	1,036	19.9	**216,429**	**192,947**	**173,741**
13,000	2,495	1,123	21.56	**212,907**	**189,807**	**170,914**
14,000	2,687	1,209	23.22	**209,697**	**186,945**	**168,337**
15,000	2,879	1,296	24.88	**206,752**	**184,320**	**165,973**

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16,000	3,071	1,382	26.53	**204,035**	**181,897**	**163,791**
17,000	3,263	1,468	28.19	**201,514**	**179,650**	**161,768**
18,000	3,455	1,555	29.85	**199,167**	**177,558**	**159,884**
19,000	3,647	1,641	31.51	**196,972**	**175,600**	**158,121**
20,000	3,839	1,727	33.17	**194,911**	**173,764**	**156,467**

Source: Eng. Walid AL-SHAAR

Figures 5 and 6 show the variation of the values of Coefficient ***β*** in Residential areas with 25% volume over capacity ratio and based respectively on minimum and maximum rate of trip generation.

Third Design Model proportionality factors (Δ)

Results depicted here are limited only for residential areas with an average of 1 parking basement for all buildings (because of numerous scenarios of number of parking basements (numbers ranging from 1 to 6))

The calculations of the coefficient Δ were made for a lot of Population where the number of residents is within the range is from 500 to 100,000 residents

Table 9: Coefficient Delta Δ in RESIDENTIAL AREAS with 1 parking basement

LandUse Area (m2)	**LandUse Area (mi2)**	**Parking Area (m2)**	**Number of car park spaces**	**Number of residents**	**Coefficient Δ**
8,085	0.003	4,204	217	500	**10,620,497**
16,171	0.006	8,409	434	1,000	**6,416,468**
80,853	0.031	42,044	2,170	5,000	**1,991,337**
161,707	0.062	84,088	4,340	10,000	**1,203,084**
242,560	0.094	126,131	6,510	15,000	**895,938**
323,413	0.125	168,175	8,680	20,000	**726,855**

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404,266	0.156	210,218	10,850	25,000	**618,009**
485,119	0.187	252,262	13,020	30,000	**541,290**
565,972	0.219	294,305	15,190	35,000	**483,904**
646,825	0.250	336,349	17,360	40,000	**439,136**
727,678	0.281	378,392	19,530	45,000	**403,099**
808,531	0.312	420,436	21,700	50,000	**373,376**
889,384	0.343	462,480	23,870	55,000	**348,380**
970,237	0.375	504,523	26,040	60,000	**327,025**
1,051,090	0.406	546,567	28,210	65,000	**308,538**
1,131,943	0.437	588,610	30,380	70,000	**292,355**
1,212,796	0.468	630,654	32,550	75,000	**278,053**
1,293,649	0.499	672,697	34,720	80,000	**265,308**
1,374,502	0.531	714,741	36,890	85,000	**253,869**
1,455,355	0.562	756,784	39,060	90,000	**243,536**
1,536,208	0.593	798,828	41,230	95,000	**234,149**
1,617,061	0.624	840,872	43,400	100,000	**225,578**

Source: Eng. Walid AL-SHAAR

Figure 7 shows the variation of the values of Coefficient Δ in Residential areas with 1 parking basement.

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CONCLUSION

The proposed research plan accounts for an important city planning/control concern.

The knowledge of cities conflicts associated with unplanned urban expansion and population growth, can identify the level of saturation of the city in terms of transportation and lead to identify the main problems.

It is highly recommended to define criteria and design models, to make implementations and integrating the planning of roadway transportation systems into city planning and inter-city planning.

In Lebanon, cities are encountering many social and economic problems in terms of high population density and high unemployment rate.

Besides:

a- The roadway transportation flow is not well distributed

b- Frequent congestions are daily observed in Lebanese road network.

c- In addition to all the above problems, unbalanced infrastructure constitutes a significant issue.

RECOMMENDATIONS

This research should be followed by other research subjects such as:

- The best fit of road network distribution into the city (Simulations)
- Finding the solution of car parkings and the measures to minimize the road friction
- Dissipating the road flow, eliminating the congestion and minimizing the road service delay/queuing time without adding new road sections more than the required as recommended by the design models.
- It is required to identify the needed actions to be enhanced to solve the problem of cities saturation.
- Proposing the preparation of legal urban planning standards to be used by developer/city users.
- Identify the simplest way to move throughout the city, accessing the city center areas, and encouraging people to use the public transportation or Para-transit pseudo systems.

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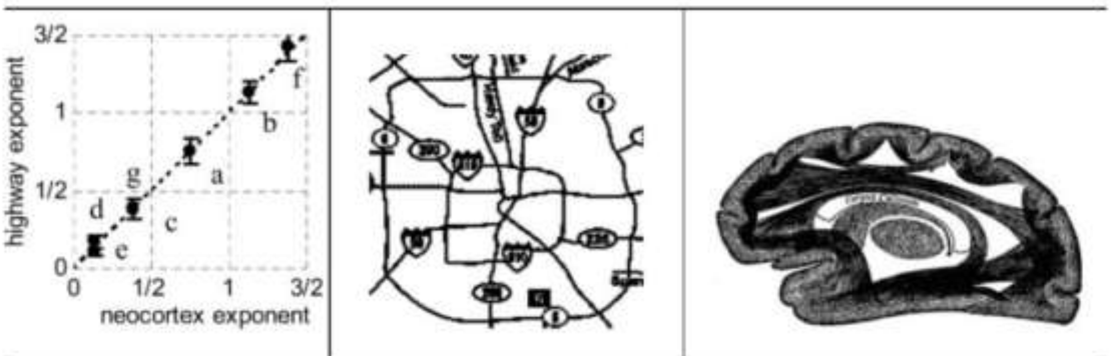
DECLARATION OF INTEREST

The author reports no conflicts of interest. The author alone is responsible for the content and writing of this article.

10. List of Figures

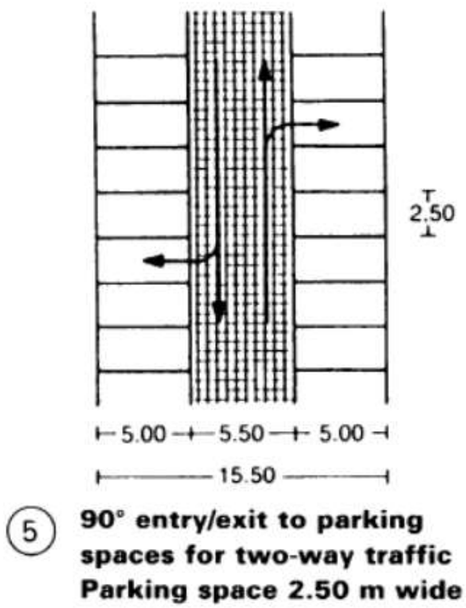
Fig. 1. Comparison of City Highway System and Neocortex Exponents for Quantities as a Function of Surface Area



Generic Name	Variable for City Highways	City Highway System Exponent	Variable for Neocortex	Neocortex Exponent
Surface area	Land area	1	Total convoluted surface area	1
(a) No. of conduits	No. of highways	0.759 (±0.083)	No. of pyramidal neurons	3/4 = 0.75
(b) Total no. of leaves	Total no. exits	1.138 (±0.072)	Total no. of synapses	9/8 = 1.125
(c) No. of leaves per conduit	No. of exits per highway	0.379 (±0.064)	No. of synapses per neuron	3/8 = 0.375
(d) Diameter of conduit	No. of highway lanes	0.174 (±0.038)	Diameter of white matter axon	1/8 = 0.125
(e) Propagation velocity	Velocity of cross-city travel	0.108 (±0.021)	Propagation velocity of white matter axon	1/8 = 0.125
(f) Total surface area of conduits	Total surface of highways	1.433 (±0.096)	Total surface area of white matter axons	11/8 = 1.375
	Population	1.462 (±0.141)		
			Total volume of white matter axons	3/2 = 1.5
(g) No. of compartments	No. of concentric ring regions	0.390 (±0.055)	No. of cortical areas	3/8 = 0.375

Source: CHANGIZI, M. A. and DESTEFANO, M. (2009)

Fig. 2. Turning and parking space



Source: Ernst, N. (2009) Architects' Data 3rd edition, p. 437

Figure 3: Coefficient α in Industrial areas with 25% volume over capacity and minimum rate of trip generation (0.12)

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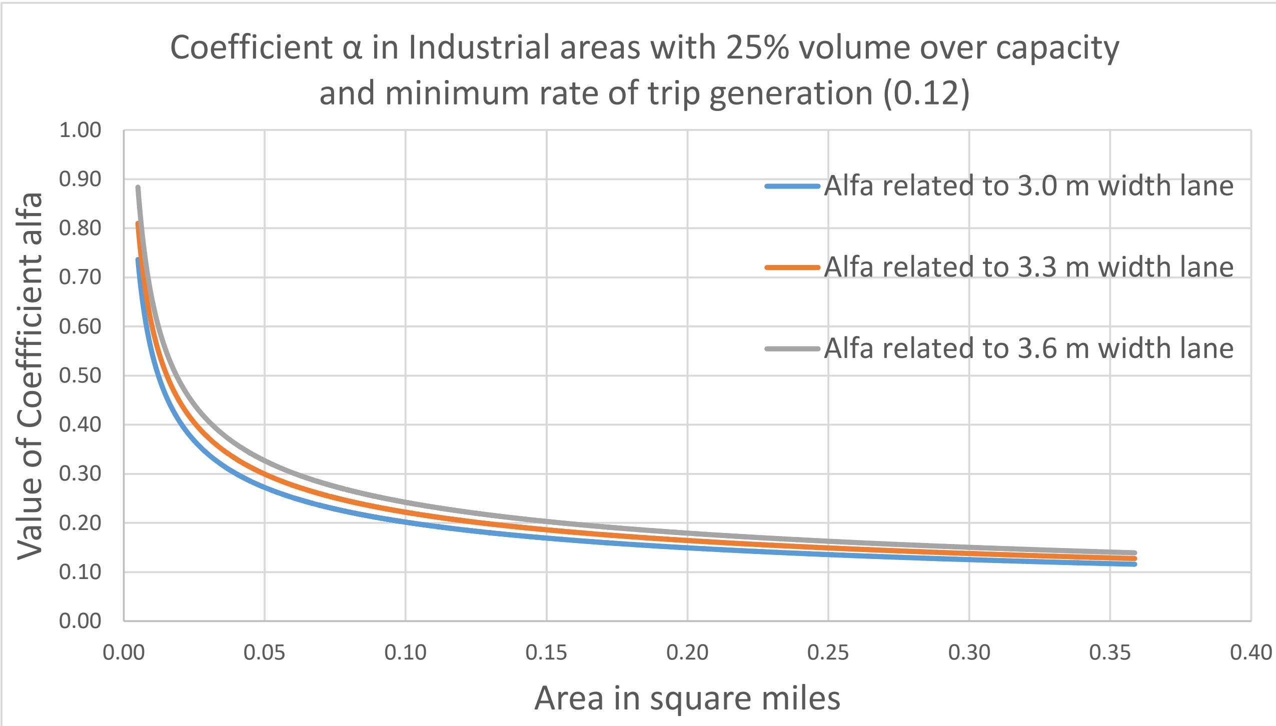

Source: Eng. Walid AL-SHAAR

Figure 4: Coefficient α in Industrial areas with 25% volume over capacity and maximum* accepted rate of trip generation (0.565)

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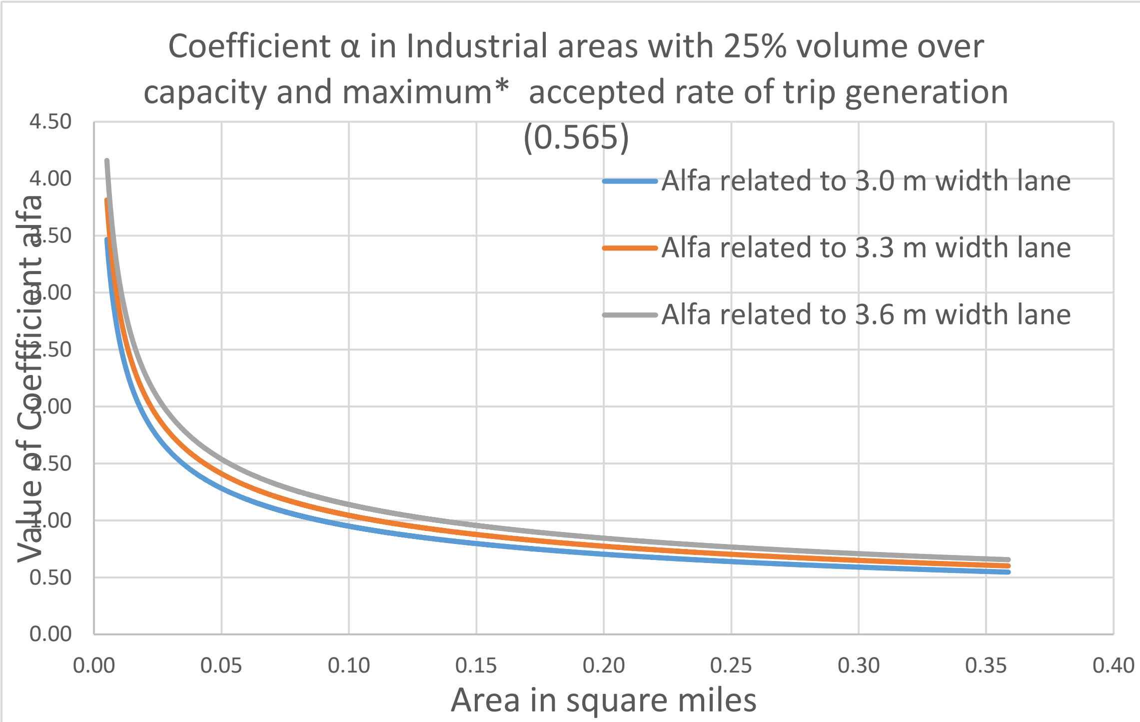
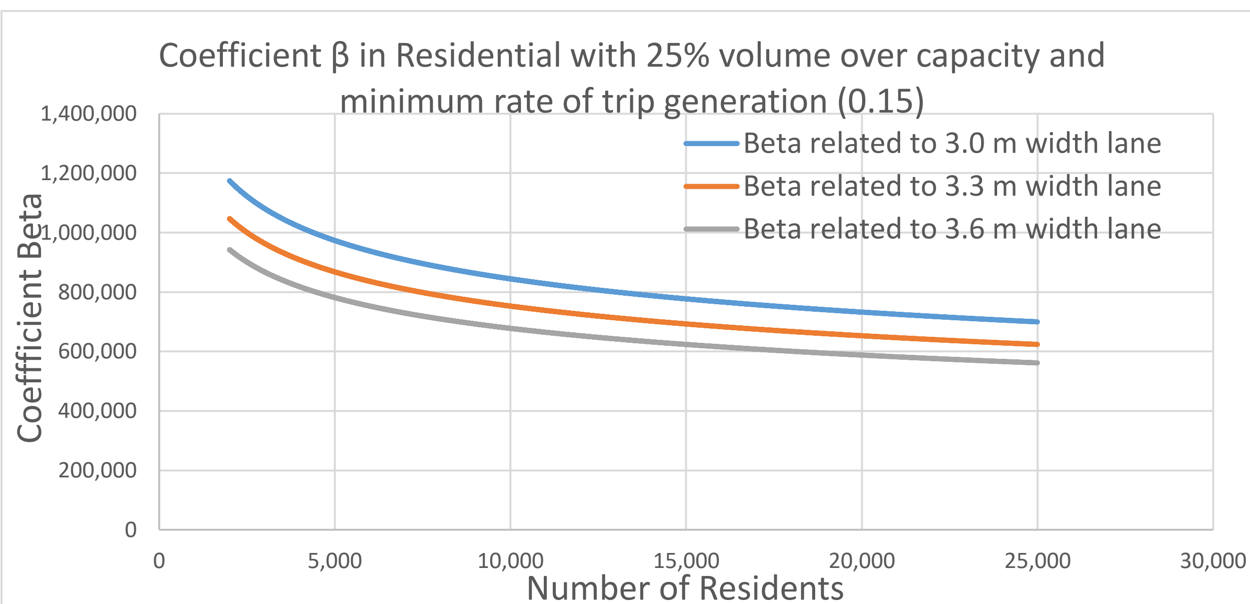


Source: Eng. Walid AL-SHAAR

Figure 5: Coefficient β in Residential with 25% volume over capacity and minimum rate of trip generation (0.15)



Source: Eng. Walid AL-SHAAR

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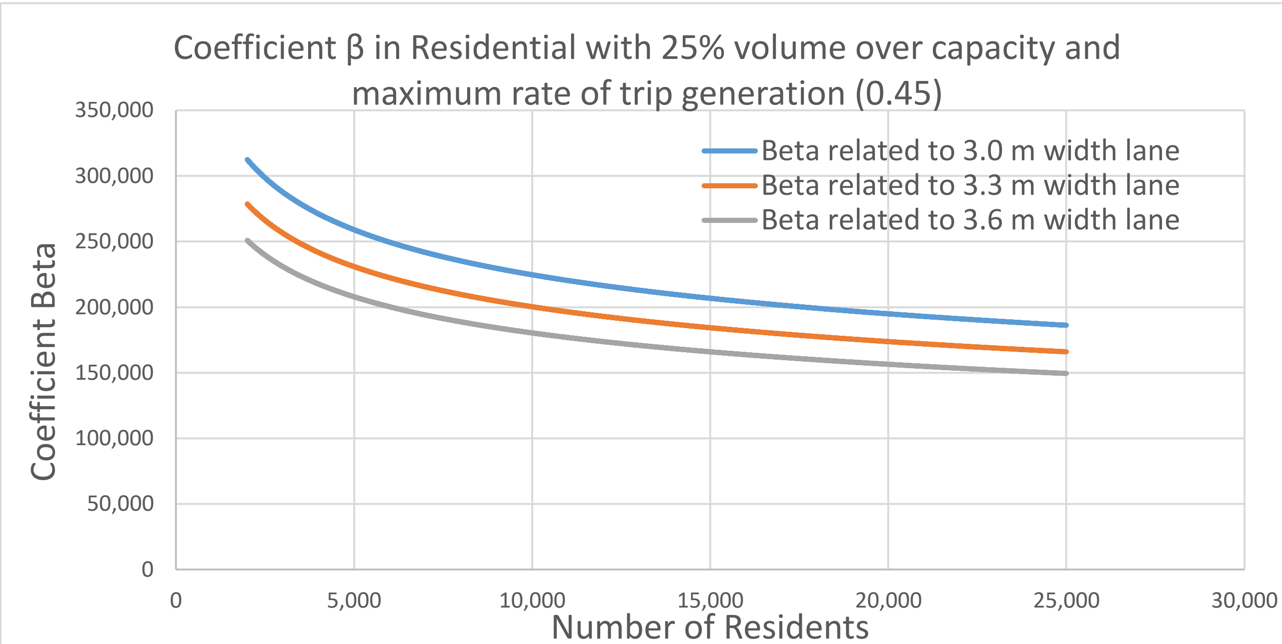
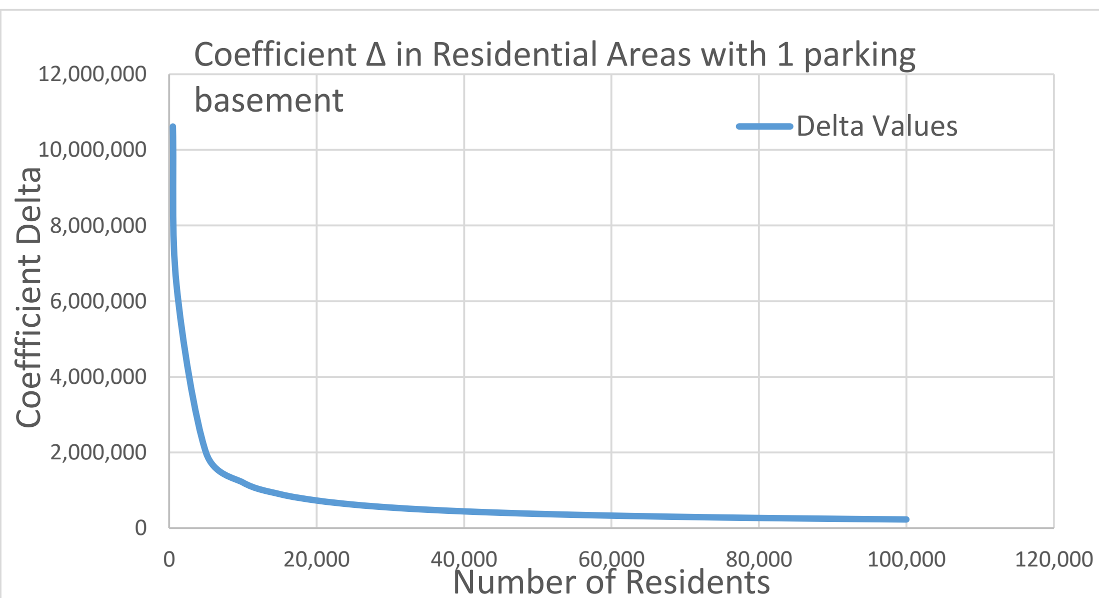
Figure 6: Coefficient β in Residential with 25% volume over capacity and maximum rate of trip generation (0.45)



Source: Eng. Walid AL-SHAAR

Figure 7: Coefficient Δ in Residential Areas with 1 parking basement



Source: Eng. Walid AL-SHAAR

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Author:

Walid AL-SHAAR
Beirut, Lebanon
Mobile phone: +96170271243
E-mail: walid-al-shaar@hotmail.com

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