Developing Trip Generation Rates for Hospitals in Amman

Mohammad Naser [1]***, Sa'ad Abu Qdais*** [2] ***and Hossam Faris*** [3]

[1] Assistant Professor, Department of Civil Engineering, Faculty of Engineering and Technology, The University of Jordan.
[2] Professor, Department of Civil Engineering, Faculty of Engineering, Jordan University for Science and Technology.
[3] Assistant Professor, Business Information Technology Department, King Abdulla II School for Information Technology, The University of Jordan.

ABSTRACT

Traffic Impact Assessment (TIA) for proposed developments often relies on trip rates obtained from historical studies. One of the most commonly used references for estimating trip rates for different proposed land uses is the Institute of Transportation Engineers' (ITE) trip generation manual. There are many issues related to the accuracy levels associated with using ITS trip generation rates within the U.S. and for sites in other countries. This study focused on developing trip generation rates for hospitals in the city of Amman, where twenty one hospitals were surveyed during average weekdays and two categories of data were collected for each hospital; various traffic volume counts and specific descriptive information about the hospital including its area, number of beds and number of available parking stalls. This study showed that trip generation models developed in the ITE trip generation manual will not produce accurate estimates that could be used for proposed hospital sites. Several methods were used to develop hospital trip generation models, including single variable regression, multivariate regression and MLP algorithms. The data analysis showed that the number of patient beds and the gross floor area were the main factors affecting the number of hospital vehicle trip generation.

KEYWORDS: Trip generation, Traffic impact assessment, Transportation planning, Urban transportation modeling system, Hospitals.

INTRODUCTION

In order to estimate the future performance of the existing or developed transportation system, the most commonly used tool is transportation modeling. The basics of transportation modeling principles were developed during the 1950s in the U.S., and since then it became an essential component of transportation planning, investment and policy development all over the world (Martens, 2006).

The traditional transportation planning models are based on the Urban Transportation Modeling System (UTMS) or as it is more widely known as the 4-step model. This is mainly due to the fact that it consists of four major steps; trip generation, trip distribution, mode choice and traffic assignment (Mayer, 2006). The UTMS is based on the principle that demand for travel is derived from the need to participate in different activities, thus the estimation of travel demand is based on estimating the need to perform these activities. Despite the criticism of the UTMS model, it remains widely used in many countries around the world with some modifications to evaluate some of the emerging needs such as environmental impact assessment and parking management strategies. The data generated by the UTMS model is utilized to assess the future

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performance of the transportation system, indentify the deficiencies in the system and evaluating possible alternatives.

The trip generation step of the UTMS model is of key importance, where the estimate of the demand for the transportation system is carried out on daily or peak period basis. Mainly, this step estimates the number of trips produced and those attracted by the zones included in the study. This is performed based on different socio-economic characteristics of the zones using large-scale travel data, where different models are used to estimate productions and attractions.

Traffic Impact Assessment (TIA) for proposed developments is an evaluation of the effects of that particular development on its surrounding and supporting transportation infrastructure and how those effects can be mitigated. TIA of proposed developments often relies on trip rates obtained from historical studies. One of the most commonly used references for estimating trip rates for different proposed land uses is the Institute of Transportation Engineers' (ITE) trip generation manual. The ITE trip generation manual relies mainly on the physical features of the proposed development for estimating its generated traffic.

The approaches for estimating the trip generation in the ITE trip generation manual are mainly based on direct estimation or rate adjustment for rates based on regression analysis or empirical data (NCHRP, 2013). There are many issues related to the accuracy levels associated with using ITS trip generation rates within the U.S. and for sites in other countries. Several studies were conducted to identify local trip generation rates that better reflect the case study conditions than what is presented in the ITE trip generation manual. Those studies showed that differences in the trip generation rates for the case studies and the rates presented in the ITE trip generation manual could amount to double the rates (Majbah Uddin et al., 2012). This could be attributed to differences in the case study demographic and economic properties, in addition to different trip making behavior. However, the ITS trip generation manual remains one of the most comprehensive sources for trip generation rates for different types of development.

This study focused on identifying more accurate trip attraction rates for hospitals than values found in the ITE trip generation manual to be used, where the conditions are similar to those of the study area used for this research. The study area used was the city of Amman, the capital of Jordan, which has witnessed very rapid urbanization and high increase in motorization levels in recent years. According to 2012 official reports (Jordan Statistical Yearbook, 2012), Amman had a population of 2.47 million, with an average population density of 326.6 inhabitants per km^2. The prevailing trend of land use is mixed use, where residential areas often include some type of commercial and service developments. It is vital to have accurate estimates of trip generation rates for proposed hospitals in order to be able to predict the impact of those hospitals on the transportation system.

METHODOLOGY AND CASE STUDY

This study focused on developing trip generation rates for hospitals in the city of Amman. According to recent statistics (Ministry of Health, 2012), there were 106 hospitals in the Hashemite Kingdom of Jordan out of which 52 hospitals were located in Amman providing an average of 27 beds per 10,000 inhabitants. As can be seen from Figure (1), there has been an increase in the number of hospital beds by 10% over the past few years with the increase in its population.

This study aimed to develop reliable trip generation rates for hospitals in the city of Amman and provide good basis for future research towards building a comprehensive trip generation database for local agencies. The methodology plan followed in this study is shown in Figure (2).

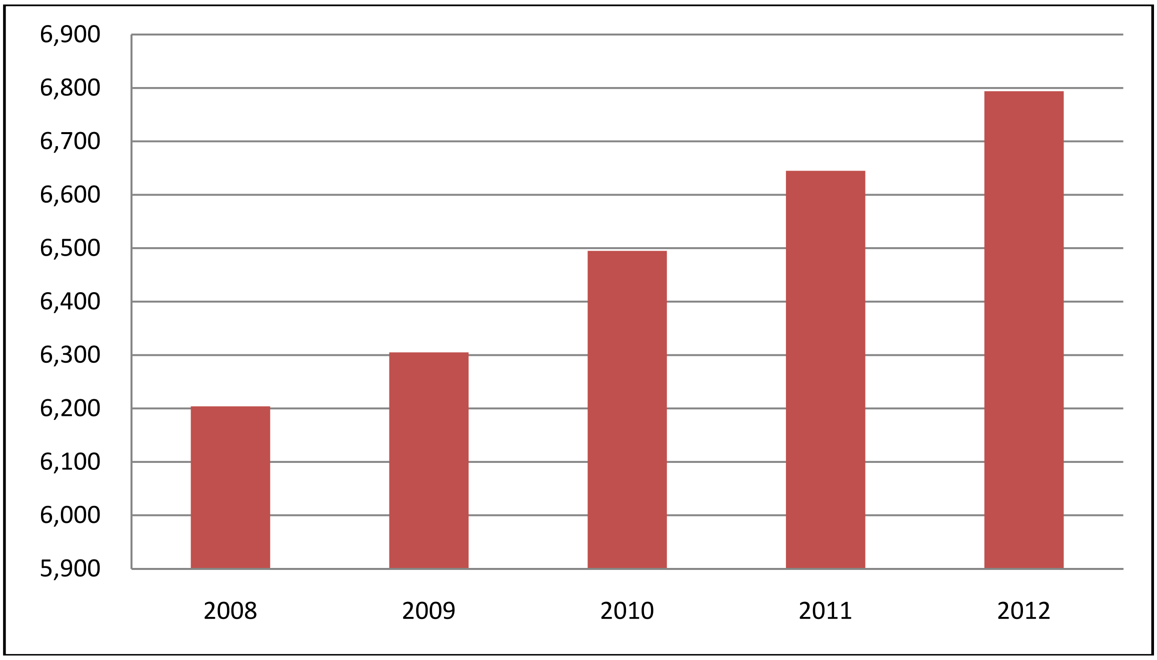

Figure (1): Number of hospital beds in Amman (2008-2012)

For the purposes of this study, twenty one hospitals were surveyed during average weekdays and two categories of data were collected for each hospital; various traffic volume counts and specific descriptive information about the hospital including its area, number of beds and number of available parking stalls were identified as the independent variables. Data regarding those variables were collected using the hospitals' administrative records. The hospitals surveyed were Arab Medical Center, Amman Surgical Hospital, Specialty Hospital, Farah Hospital, Luzmila Hospital, Jordan Hospital, Ibn Al-Haitham Hospital, Istishari Hospital, Al-Khalidi Hospital, Islamic Hospital, King Hussein Cancer Center, Eye Specialty Hospital, Al-Amal Maternity Hospital, Al-Rasheed Hospital, Palestine Hospital, The University of Jordan Hospital, Italian Hospital, Queen Alia Military Hospital, Al-Ahli Hospital, Istiklal Hospital and Al-Isra' Hospital.

The traffic volumes for vehicles entering and exiting the hospitals were recorded manually. At each entry and exit point of a hospital, the generated vehicle trips were counted for two days within the week days. The counts were carried out during summer months when the generated hospital trip rates are expected to be high to reflect the most critical traffic movement in the absence of reliable traffic volume expansion factors for the city of Amman. Fifteen minute intervals were used in recording the traffic volume for the vehicle trips entering and exiting each hospital, and also in estimating the arrival and departure patterns for vehicle trips. Directional distributions of entering and exiting vehicle trips, percentages of patients, visitors and employees, and percentages of inpatients and outpatients were estimated during the peak hours based on a questionnaire distributed on a randomly selected sample of people arriving and leaving the hospital during the peak periods.

The following are definitions of the key variables and terminologies used for hospital trip generation rates:

- Number of beds: all patients' beds available in the hospital rooms.
- Gross floor area: the total square meters in the hospital's main building.

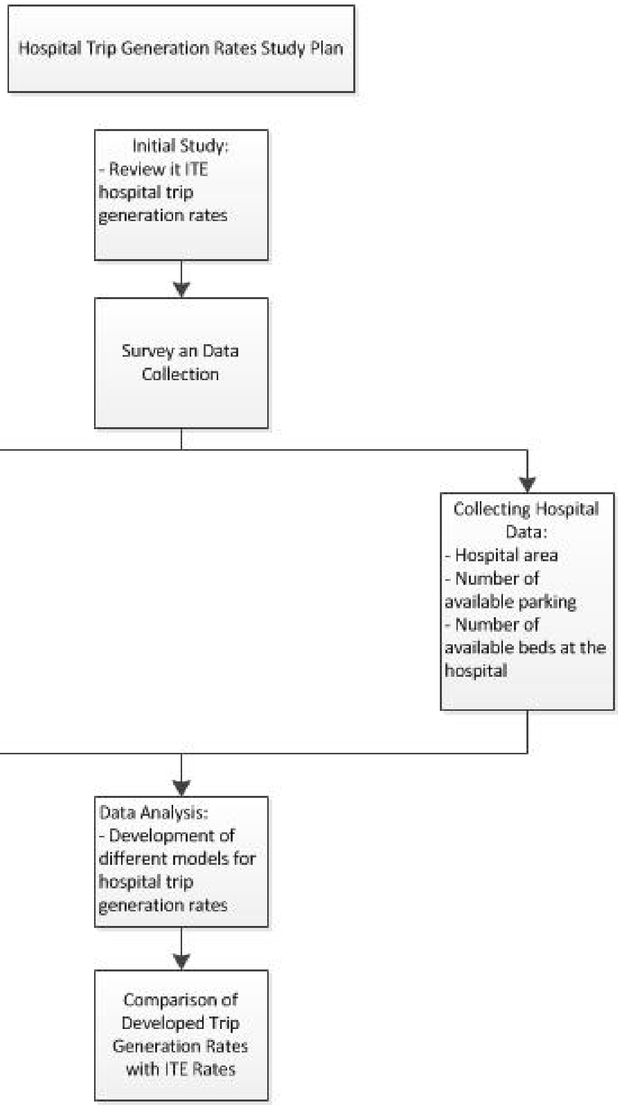

Figure (2): Study plan

- Day time period: time of the day that extends from 7a.m. to 7p.m.
- Vehicle trips: Total number of trips that are generated by a hospital during day time.
- Attracted vehicle trips: Total number of vehicles which enter a hospital during the day time period.
- Produced vehicle trips: Total number of vehicles which leave a hospital during the day time period.
- Peak hour: The one hour of the day that has the highest number of trips.
- Peak hour of generation: The one hour of the day that has the highest number of vehicular movements (in and out).
- Attracted trip rate: Number of attracted vehicle trips per unit of physical land use parameter.
- Produced trip rate: Number of produced vehicle trips per unit of physical land use parameter.
- Trip generation rate: Number of vehicular movements per unit of physical land use parameter.

Table 1. Attracted trip single variable prediction models

Variable	Gross floor area (/100 m^2)	Number of beds	Available parking stalls
Model	A = 67.5 + 0. 389 X_1	A = 73.3 + 0.348 X1	A = 97.8 + 0.0957 X1
Adjusted R^2	56.3%	52.5%	36.6%

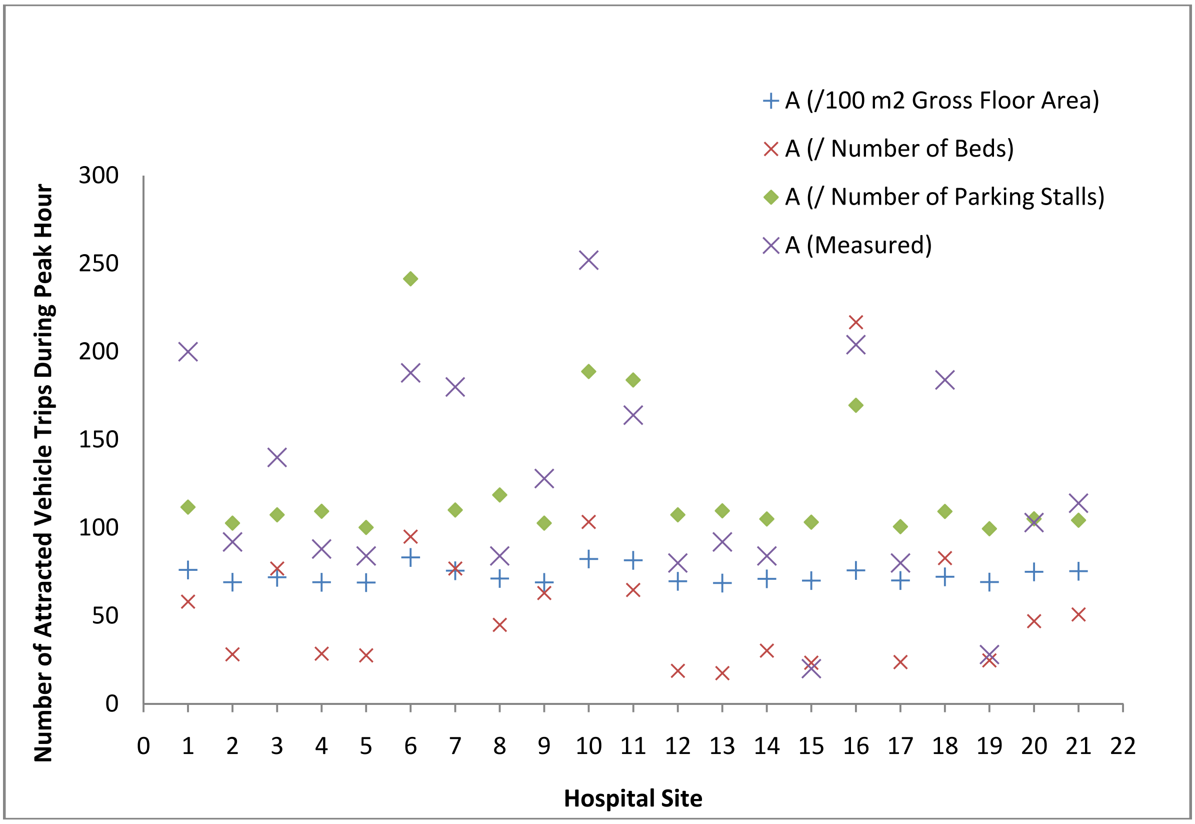

Figure (3): Single variable hospital vehicle trip attraction prediction models *vs.* actual data collected

ANALYSIS OF RESULTS

Several analysis methods were used to produce hospital trip generation models that best predict the number of trips generated by hospitals based on the area (m^2), the number of beds and the number of available parking stalls. The methods used for model development included regression, genetic algorithms and multi-layered perception. The most commonly used method for developing trip generation rates is regression, which is a statistical methodology that is concerned with relating a response to a set of predictor independent variables in order to develop a prediction equation (model) with the least possible error of prediction (Mendenhall and Sincich, 2011). The t-statistics were used at a confidence level of 95% to evaluate the statistical significance of the coefficients associated with the different variables used in developing the equations. Also, residual analysis was conducted to check the validity of the assumptions of the developed models.

In addition, this study developed prediction models using multi-layered perception (MLP) which is a type of neural network algorithm used for approximation. MLP consists of a group of neurons (or interconnected processing elements) arranged in two or more layers and interacting with each other through weighted connections. The strength of the influences between the interconnected elements is verified by those weights. To compare developed models' fit to the data, the adjusted R^2 values were used. These values indicate how close the developed models' are to the original data points. The closer the values to one, the better the model fit. The results from the application of the previous methods are summarized in the following paragraphs.

There were two sets of models developed for the purposes of this study; using a single variable to predict the number of trips generated, or using multiple variables in the same model for trip prediction. The results from the single variable models for trips attracted to hospitals during the peak periods are summarized in Table (1) and the results of the models are illustrated in Figure (3). As it can be seen from the values of the adjusted R^2 values and the figures, those models performed poorly in explaining the variation in the number of attracted vehicle trips attributed to variation in the factors used in the models.

Table (2) summarizes the results from the single variable models for trips produced by hospitals during the peak periods. The results from the hospital peak hour trip productions are illustrated in Figure (4).

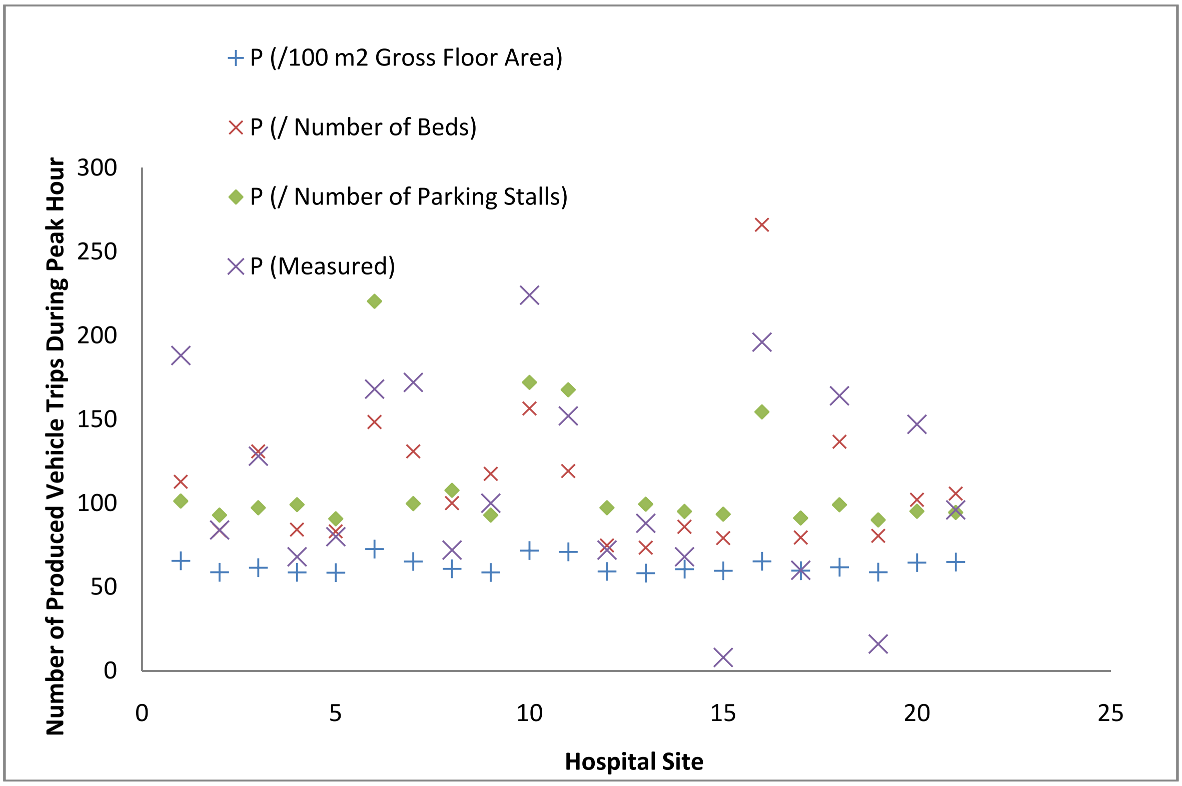

Figure (4): Single variable hospital vehicle trip production prediction models *vs.* actual data collected

As it can be seen from the values of the adjusted R^2 for all the models, the maximum value was 56.9%. This indicates the models' insufficient ability to predict the number of trips attracted to, or produced by hospitals. Based on the previous analysis, multivariate models were developed to improve the ability to predict the number of hospital trips generated during peak periods. The results of the developed multivariate models are summarized in Table (3).

Table 2. Produced trip single variable prediction models

Variable	Gross floor area (/100 m^2)	Number of beds	Available parking stalls
Model	P = 57.2 + 0.382 X_1	P= 63.7+ 0.336 X_1	P = 88.5 + 0.0879 X_1
Adjusted R^2	56.9%	51.2%	31.7%

Table 3. Hospital trip generation multivariate prediction models*

Trip generation	Prediction model	Adjusted R^2
Trips attracted to hospitals	A = 48.3 + 0. 365 Ar + 0.235 B - 0.0411 Pa	70.3%
Trips produced by hospitals	P = 35.0 + 0. 420 Ar + 0.234 B - 0.0627 Pa	73.1%

* where, Ar: 100 m^2 of hospital gross floor area;
B: Number of hospital beds;
Pa: Number of available parking stalls in the hospital.

The value of the adjusted R^2 of the multivariate trip generation models improved when compared to single variable models, which indicates increased model predictive ability. The results from the multivariate model showed that both the hospital gross floor area and the number of hospital beds were significant in both models. However, the number of available parking stalls was not significant. Stepwise regression was utilized for variable screening to produce models containing only variables that are significant at the desired confidence level. The results of stepwise regression analysis are presented in Table (4) and shown in Figures (5) and (6).

As can be seen from Figures (5) and (6), the most noticeable discrepancies were between modeled values and actual data for hospitals (15) and (19), and this is explained by the very low traffic counts at those locations which are considered to be unattractive to patients who prefer to go to other available hospitals. This affected the developed models' ability to accurately capture the number of trips produced by or attracted to those sites.

In addition to regression analysis, the data in this study was tested using multi-layered perception (MLP) models to improve the model performance. MLP models are known for being useful in research, especially for fitness approximation problems. The general form for the sigmoid activation function used for model development is:

$$y(v_i) = (1 + e^{1v_i})^{-1} \ldots \qquad \text{Equation (1)}$$

The MLP models had a value of adjusted R^2 of 87.8% for attractions and 87.3% for productions when compared to the actual data collected. The MLP model parameters are summarized in Tables (5) and (6). The modeled results from the MLP algorithms compared to measured values are presented in Figures (7) and (8). As can be seen from those two figures, the most noticeable discrepancies were between modeled values and actual data for hospitals (10), (15) and (19). The cases for hospitals (15) and (19) were explained by the very low traffic counts at those locations, since they are considered to be unattractive to patients who prefer to go to other available hospitals. On the other hand, hospital (10) is known for its good reputation and therefore is considered to be highly attractive.

Table 4. Hospital trip generation multivariate prediction models*

Trip generation	Prediction model	Adjusted R^2
Trips attracted to hospitals	A = 55.28+ 0. 260 Ar + 0.215 B	72.87%
Trips produced by hospitals	P = 34.98+ 0. 420Ar + 0.234B - 0.0627 Pa	74.17%

* where, Ar: 100 m^2 of hospital gross floor area;
B: Number of hospital beds;
Pa: Number of available parking stalls in the hospital.

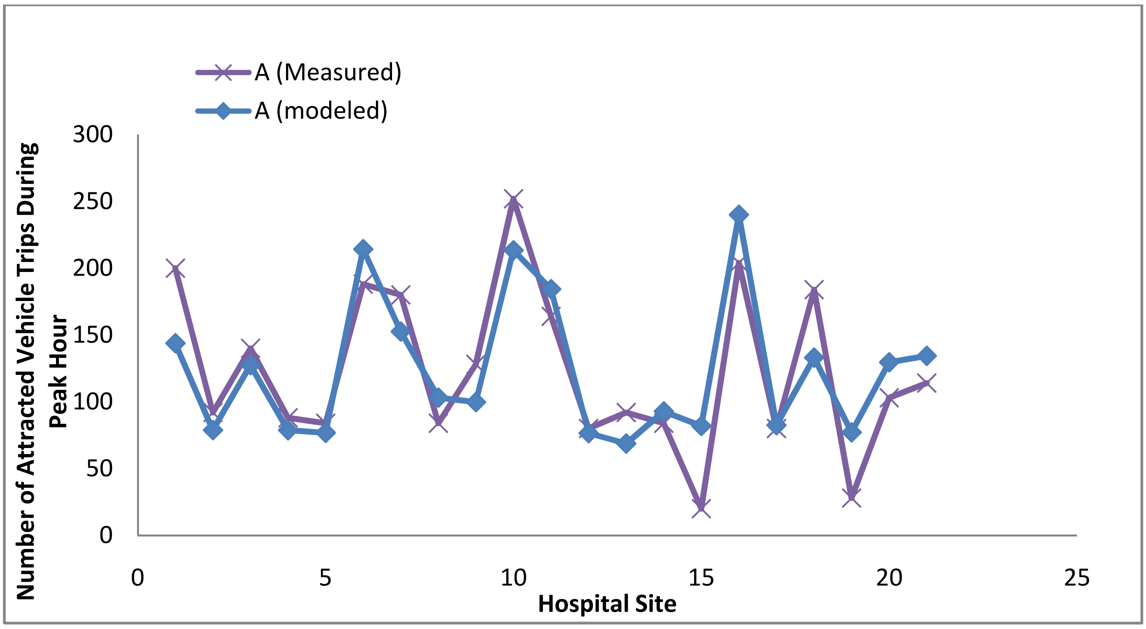

Figure (5): Multiple variable hospital vehicle trip attraction prediction models *vs.* actual data collected

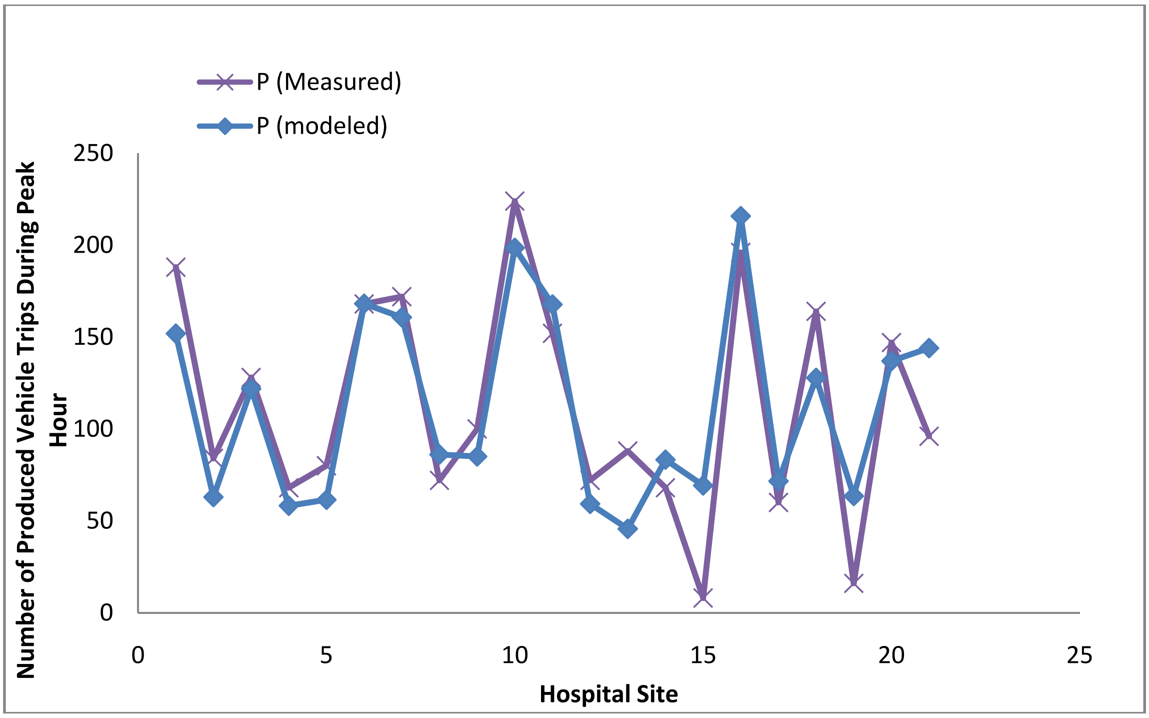

Figure (6): Multiple variable hospital vehicle trip production prediction models *vs.* actual data collected

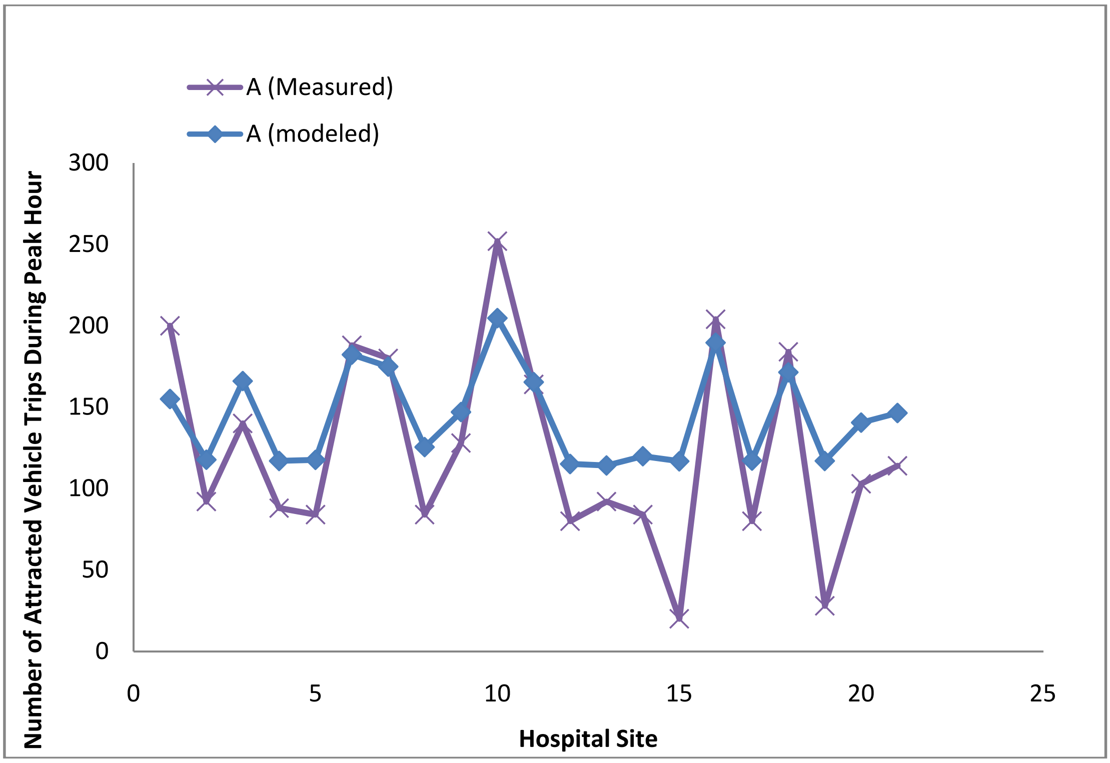

Figure (7): MLP hospital vehicle trip attraction prediction models *vs.* actual data collected

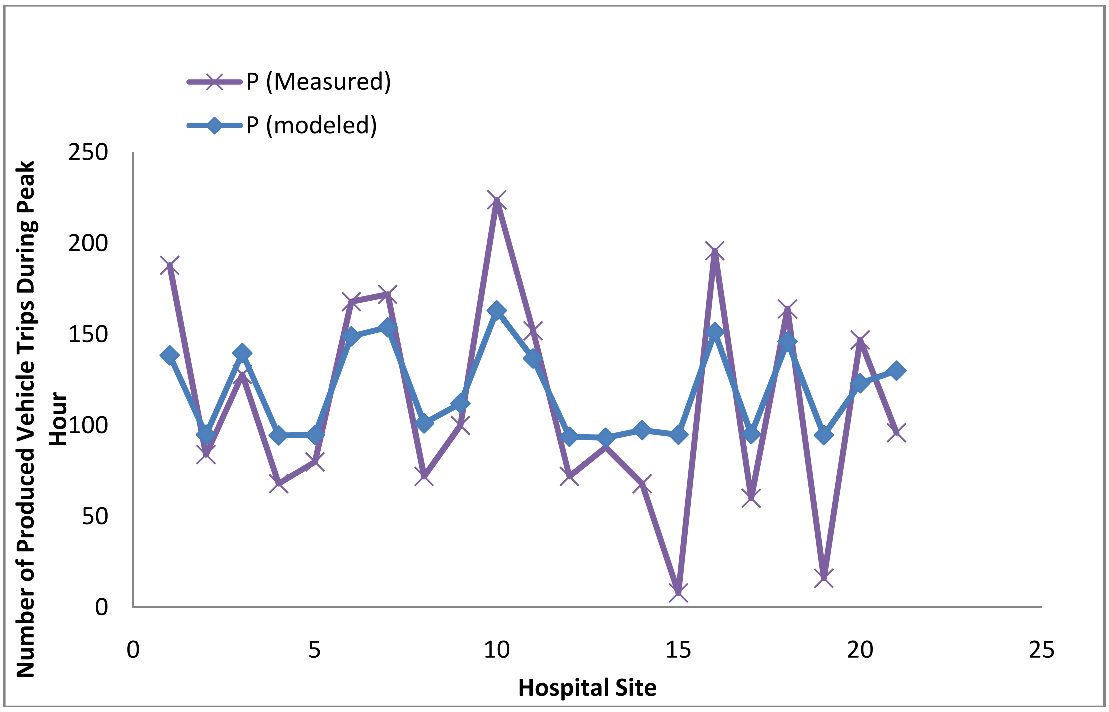

Figure (8): MLP hospital vehicle trip production prediction models *vs.* actual data collected

Table 5. MLP multivariate hospital trip attraction prediction model*

Node 1		1.206349	Threshold	-0.57826
Node 2		0.888437		
Node 1	Ar	0.413911	Threshold	2.310865
	B	6.649689		
	Pa	-1.66045		
Node 2	Ar	2.928917	Threshold	-1.7812
	B	-0.47393		
	Pa	-0.08476		

* where, Ar: 100 m^2 of hospital gross floor area;

B: Number of hospital beds;

Pa: Number of available parking stalls in the hospital.

Table 6. MLP multivariate hospital trip production model*

Node 1		-0.71083	Threshold	-0.42265
Node 2		1.694857		
Node 1	Ar	0.487305	Threshold	-0.76807
	B	2.391879		
	Pa	-0.87496		
Node 2	Ar	1.906159	Threshold	2.112939
	B	5.82489		
	Pa	-1.94179		

* where, Ar: 100 m^2 of hospital gross floor area;

B: Number of hospital beds;

Pa: Number of available parking stalls in the hospital.

To check the validity and transferability of the MLP models for trip attractions and trip productions, data was gathered and tested based on previous studies. The data was obtained from a study performed for hospital trip attractions in Jordan for three hospitals (Palestine, Al-Istiqlal and Al-Esra' hospitals) in 2007 (Abu-Ameerah, 2007). The actual observed number of trips attracted to and produced by those hospitals were obtained from the study and compared to the values produced by the MLP models. The results of the comparison are summarized in Table (7). It can be seen from Table (7) that MLP models provided good estimates of hospital trip generation during the peaks for Al-Istiqlal and Al-Esra' hospitals. On the other hand, the models provided poor estimates of trips generated by Palestine hospital. This result is attributed to other factors that affected the attractiveness of that hospital to patients who seem to prefer to go to other available hospitals.

Table 7. Comparison of actual observed number of trips attracted to and produced by certain hospitals with values produced by the MLP models

Hospital	Attractions			Productions		
	Observed	Estimated by MLP model	% Difference	Observed	Estimated by MLP model	% Difference
Palestine	37	117	68%	36	95	62%
Al-Istiqlal	132	141	6%	134	123	-9%
Al-Esra'	118	114	-4%	116	130	11%

CONCLUSIONS

Hospital numbers are increasing rapidly in the city of Amman, and they are considered major trip generators that will have a major effect on the operating conditions of the transportation system in their vicinity. This study of twenty one major hospital sites in Amman showed that trip generation models developed in the ITE trip generation manual will not produce accurate estimates that could be used for proposed hospital sites. The 8th edition ITE trip generation rate for hospitals was 1.31 vehicle trips per bed during the peak hours; while the case study rate was 1.84 trips per bed. This could be attributed mainly to the differences in socio-economic factors between the local population and the ITE trip generation manual case study population.

The data analysis showed that the number of patient beds and the gross floor area were the main factors affecting the number of hospital vehicle trips generated. However, each one of these factors provided inaccurate estimates of hospital vehicle trip generation. Several methods were used to develop hospital trip generation models, including single variable regression, multivariate regression and MLP algorithms. MLP algorithms produced the best models when the estimated values were compared to the collected hospital data with adjusted R^2 values up to 87.8%.

There are very few studies related to local trip generation rates for different land uses, where the rates developed in this study could be used for further research towards developing local trip generation rates' database. This study showed the importance of having a local database to acquire accurate estimates of the impact of proposed hospitals on the transportation system in the city of Amman.

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