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Trip and Parking Generation of Hospitals and Medical Centers in Jordan

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ABSTRACT

Estimating trip and parking generation for different land uses is vital for transportation planning, design and management purposes. This study was carried out to develop trip and parking demand for hospitals and medical clinic centers (MCCs) in Jordan. Based on field investigation and predefined criteria, fifteen hospitals and twenty MCCs were selected. Attracted and generated trips, as well as parking demand, were manually surveyed during workdays and holidays. In addition, data on characteristics of the selected sites were obtained.

Based on hospital and MCC attributes, peak trip rates were computed for AM and PM periods. According to the maximum peak, rates/models were developed to estimate attracted and generated trips as well as parking demand. Compared with those used in the developed countries, values obtained in this study are relatively low, except for the value of trip generation for hospitals. Therefore, it is recommended to conduct further studies to establish a trip and parking generation manual for local use in Jordan rather than relying on manuals developed for other countries or by studies of limited scale.

KEYWORDS: Trip generation, Parking demand, Hospitals, Medical clinic centers, Jordan.

INTRODUCTION

Estimating trips and parking demand generated from different land uses or new developments is vital for transportation planning, design and management purposes. Trip generation is the most important step in the four-step based model (Juan and Luis, 2011; Regidor, 2006). It provides the foundation for the travel demand forecasting process and therefore accuracy of estimation is essential, since it can propagate the errors into the entire forecasting process. Thus, the uses of adequate trip or parking models/rates may help town planners and traffic engineers set an efficient street network, provide an acceptable level of service and avoid possible negative impacts on the surrounding area. For example, establishing a hospital in an area requires accurate estimate of the traffic generated by the hospital and the impact of this generated traffic on the adjacent street network as well as undertaking measures to avoid probable congestion and traffic-accident problems. Similarly, sufficient off-street parking supply should be provided to avoid obstructions of adjacent streets and improve attractiveness for potential customers.

In Jordan, trip and parking generation manuals have not been developed yet. In conducting traffic impact studies for new developments, traffic engineers use rates developed for other countries or make use of the findings of local small-scale studies. It is acknowledged, however, that these rates differ from one country to another due to differences in economic situation, travel habits, level of transit services and car ownership, among others (Cervero and Arrington, 2008). On the other hand, the Ministry of Municipal and Rural Affairs

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(MoMRA), the name of which has been changed recently to Ministry of Civil Administration, has regulations related to parking spaces required for certain new structures and these regulations were set based on *ad-hoc* procedures. Despite the fact that these regulations are old and not based on detailed studies, the Ministry has raised the penalty of not providing enough parking spaces from about US $ 1500 to 8500 per lot and this new penalty has been applied since 1st of August 2017. Thus, for the benefit of stakeholders and developers, detailed studies should be carried out to rationalize decisions related to trip and parking generations for different nw projects.

In the last decade, Jordan experienced a large increase in population. During the period 2007-2020, the population increased from five to more than ten millions, Part of this increase is the result of influx of refugees from Syria and Iraq, among other countries. Also, the country has an excellent reputation for medical services in the Middle-East. As such, many hospitals and medical clinic centers (MCCs) were constructed in Amman, the capital of Jordan. The city has a population of four millions and exhibited continuous development (Department of Statistics, 2015). It, however, suffers from traffic congestion along major/minor arteries due to the lack of adequate planning of new projects, such as hospitals and MCCs, among other factors. However, field observations revealed that most of clinic centers are clustered nearby hospitals. In this study, a medical clinic center (MCC) is defined as a facility that provides limited diagnostic and outpatient care, but is unable to provide prolonged in-house medical and surgical care. MCCs generally have laboratory facilities, supporting pharmacies and a wide range of services compared to medical offices, which may only have specialized or individual physicians.

The objective of this study was to estimate generated trips and parking demand for hospitals and MCCs. Both rates and regression statistical models were developed to estimate peak generated trips and parking demand. To achieve this objective, a total of 15 hospitals and 20 MCCs were selected based on predefined criteria. The selected hospitals included private and public hospitals. Peak trips and parking demand were observed during working days, weekends and holidays.

BACKGROUND

Douglass and Abley (2011) compared trip generation and parking demand related to hospitals and MCCs in different countries. They indicated that peak trip generation rates related to hospitals for Australia, the United Kingdom and the United States were 1, 1.53 and 1.45 trip/bed, respectively. Meanwhile, the peak parking demand rates related to hospitals for the three countries were 1.2, 2.27 and 4.09 space/bed, respectively. For MCCs, these countries used different measures to estimate peak trip generation, such as employees, professional staff or gross floor area (GFA). However, the peak parking demand related to MCCs for Australia, the UK and the USA was 4, 3.01 and 4.77 space/ 100 m² of GFA, respectively.

The 9th edition of the Institute of Transportation Engineers (ITE) *Trip Generation Manual* was published in 2012 and developed based on the results of more than 5500 studies (ITE, 2012). The manual involves 172 land uses; including hospitals and MCCs, among other land uses. For hospitals and MCCs, the manual indicates that the peak trip generation rates were 1.42 trip/bed and 5.18 trip/100 m² of GFA, respectively. On the other hand, the 4th edition of the ITE *Parking Generation Manual* provides the recommended parking demand for 69 land uses (ITE, 2010). The manual indicates that the parking demand for hospitals and MCCs was 7.35 spaces/bed and 4.27 space/100 m² of GFA, respectively. These figures represent the 85th percentile of peak parking rates. However, the ITE emphasizes that these values are applicable to automobile-oriented units and are not recommended for use in downtown, mixed use developments or transit oriented areas. On the other hand, Millard-Ball (2015) indicated that the *Trip Generation Manual* tends to overestimate generated trips by 55%, because its data represent a biased sample of developments in the USA and most trips generated by new developments involve reshuffling trips from other destinations. Also, five USA case studies found that transit-oriented developments created less demand for parking and driving than conventional suburb developments did (Ewing et al., 2017).

The Department of Transport of Abu Dhabi developed a manual for estimating trip and parking rates for several land uses in the United Arab Emirates (Abu Dhabi, 2012). For hospitals in Dubai, the manual

reported that the peak-hour generated trips and parking demand were 2.79 trip/bed and 1.49 space/bed. For MCCs, the peak-hour generated trips and parking demand were 7.05 trip/100 m² and 3.0 spaces/100 m² of GFA, respectively.

In Jordan, Al-Masaeid et al. (1999) estimated vehicle parking demand for different land uses; including hotels, hospitals, shopping centers, housing buildings and offices. A total of 208 sites were selected, of which 53 were hospitals. They found that the peak parking demand for hospitals varied from 0.2 to 0.6 space/bed, with an average of 0.4 space/bed. Based on regression analysis, the developed relationship had a power function form.

Finally, the Jordanian Building System and the Regulations of the Ministry of Municipal and Rural Affairs (MoMRA, 2017) are used to estimate parking requirements for various land uses in Jordan. For hospitals, 1 space/bed or 2 spaces/ 100 m² of GFA are required. For MCCs, 2 spaces/100 m² should be provided. In fact, these regulations were not based on reasonable studies or periodically updated to capture possible changes over time. Also, these regulations did not recommend any values for trip generation estimates. For the benefit of developers and the public, therefore, there is a need to estimate generated trips and parking demand for hospitals and MCCs.

METHODOLOGY AND DATA COLLECTION

For the purpose of this study, trip and parking generation surveys were conducted for the selected hospitals and MCCs in 2016 and 2017. Four criteria were adopted to select the investigated sites. These criteria included the availability of well-defined entrances/exits, adequate parking supply, mature site in a mature area and no abnormal conditions at the selected site or surrounding area. Mature site in a mature area criterion was adopted to ensure that the selected site represents the ultimate characteristics of a successful development. These criteria were set by ITE (2010), ITE (2012) and several studies (Al-Sahili and Hamadneh, 2016; Al-Masaeid et al., 2018; Al-Masaeid and Fayyad, 2018).

Based on the predefined criteria, 15 hospitals and 20 MCCs were selected (Al-Shafie, 2016; Shehadeh, 2017). These sample sizes are quite larger than the minimum sample size recommended by the ITE, which is four sites for each land use (ITE, 2010). In fact, large sample size is preferred to produce higher accuracy of estimates and large degrees of freedom for testing the significance of the developed models or parameter estimates.

Trips and parking demand were observed during working days and weekends. In Jordan, working days are Sunday through Thursday. However, the surveys were conducted on typical workdays (Monday, Tuesday and Wednesday) and on the weekend (Saturday). The number of attracted trips, produced trips, generated trips (in and out or vehicle trip ends) and parking accumulations were observed manually at 15-min intervals. Observers sat at each entrance/exit and in the parking lot/garage and continuously counted the vehicles during the period 7:00 Am-5:00 PM for hospitals and from 9:00 AM to 6:00 PM for MCCs. It is worth mentioning that only vehicles entering the hospitals or MCCs were considered in the count and this approach is consistent with the ITE (2012) procedure, Therefore, in this count procedure, the average weighted trip rates will be the same as the marginal trip rates (Millard-Ball, 2015).

Data on characteristics of the selected hospitals and MCCs was obtained from the related administrative units. This data included number of beds, GFA, number of doctors and number of employees in each hospital. Meanwhile, for each MCC, data on number of general practitioners, number of specialized doctors, number of employees, GFA and number of clinics was obtained. Tables 1 and 2 illustrate the characteristics of the collected data for hospitals and MCCs, respectively.

Table 1. Statistical characteristics of hospitals

Variable	Mean	Range
GFA, thousand m²	35.3	7-170
Number of beds	273	91-1101
Number of doctors	252	18-700
Number of employees	1097	402-4215

Table 2. Statistical characteristics of MCCs

Variable	Mean	Range
GFA, m²	2627	605-5076
Number of doctors	22	6-50
Number of specialists	15	4-28
Number of employees	35	6-47

In the analysis, it was preferred to use planning rather than operating variables. For example, it was better to use gross floor area (GFA) or number of beds rather than number of employees, because number of employees may be affected by the type of owner/institution or available technology. Trip or parking rates were computed as the weighted average of the number of vehicle trips or vehicle parking demand per unit of related independent variable.

Finally, regression analyses were carried out to develop models for estimating peak number of trips or peak parking demand, using the Statistical Package for Social Sciences (SPSS). Several independent variables were collected on site characteristics for hospitals and MCCs. Correlation analyses were performed to identify independent variables that strongly influenced the number of trips or parking demand and explored possible multicollinearity among independent variables. Model aptness, coefficient of determination (R^2), logic and simplicity of the developed models are the main criteria for selecting an appropriate model (Neter et al., 2005). As a role, however, the *Parking Generation Manual* (ITE, 2010) and *Vermont Trip Generation Manual* (2010) used regression equations only where $R^2 \geq 0.5$; otherwise trip or parking rates are normally used for estimation purposes. For accurate prediction, models with $R^2 \geq 0.6$ were considered to be acceptable in this study.

ANALYSIS AND RESULTS

Peak Trips and Parking Demand

As stated before, trip and parking studies were conducted on typical workdays and on the weekend (Saturday). Peak trips and parking demand for hospitals occurred on workdays were compared with those on Saturday. The AM and PM peak trips were observed in the periods 8:00-9:00 and 3:30-4:30, respectively. The maximum attraction and generation trips occurred in the AM period, which coincides with the peak traffic on the adjacent streets (Al-Shafie, 2016). Also, the peak parking demand was observed in the period 8:00-9:00. In general, the AM and PM trips and parking demand on Saturday, as a holiday, represented about 90% of their corresponding values on a workday.

Unlike hospitals, peak trips and parking demand for MCCs occurred on Saturday. It was found that the peak AM and PM periods were 11:30-12:30 and 3:30-4:30, respectively and the peak attraction, generation and parking demand occurred in the AM peak period (Shehadeh, 2017). It is worth mentioning that the AM and PM peak trips and parking demand on a workday constituted approximately 80% of their corresponding values on Saturday.

Developed Peak Trip Rates and Models

Rates were computed as the weighted average of the number of trips per unit of related independent variable. Tables 3 and 4 show the obtained AM and PM peak trip rates for hospitals and MCCs, respectively.

Table 3. Peak trip rates for hospitals on a typical workday

Vehicle trip rate per	AM		PM	
	Attracted	Generated	Attracted	Generated
Bed	2.40	2.76	0.62	2.33
GFA, (100 m²)	2.28	2.97	0.57	2.50
Doctor	5.20	9.14	1.29	7.71
Employee	0.47	0.77	0.12	0.65

Table 4. Peak trip rates for MCCs on Saturday

Vehicle trip rate per	AM		PM	
	Attracted	Generated	Attracted	Generated
GFA, (100 m²)	2.76	3.39	1.04	2.40
Doctor	3.32	4.72	1.25	3.35
Employee	1.38	1.95	0.52	1.38

Based on regression analysis, Table 5 presents the maximum attracted and generated (vehicle trip ends) trip models for hospitals and MCCs in the peak AM periods. All the developed models and their parameters were found to be significant at the 95% confidence level. Residuals' analyses indicated that they were randomly distributed and no outliers were observed. Model equations with coefficients of determination (R^2) less than 0.6 were excluded. For hospitals, the GFA, number of doctors and employees were not found to be helpful in explaining variations in the attracted or generated trips. Therefore, peak attracted and generated trips were modeled using the number of beds, as an independent variable. In the case of MCCs, large variations in the number of trips were explained by the number of doctors, GFA or number of employees. Therefore, a separate vehicle trip model was developed for each determinate variable.

Table 5. AM peak attracted and generated trip models for hospitals and MCCs

Land use	Trip type	Independent variable	Model equation	R^2
Hospitals	Attracted, AT	Number of beds, NB	$AT=0.64*NB^{1.22}$	0.72
	Generated, GT	Number of beds, NB	$GT=1.20*NB^{1.15}$	0.73
MCCs	Attracted, AT	Number of doctors, Dr	AT=3.48* Dr	0.95
	Attracted, AT	GFA, (100 m²)	AT=3.0*GFA-3.84	0.84
	Attracted, AT	Number of employees, E	AT=1.43* E +21.93	0.93
	Generated, GT	Number of doctors, Dr	GT= 4.72* Dr	0.95
	Generated, GT	GFA, (100 m²)	GT=4.1* GFA	0.83
	Generated, GT	Number of employees, E	GT=2.05 E + 29.94	0.94

Developed Peak Parking Demand Rates and Models

Table 6 shows peak parking demand rates and the developed models for hospitals and MCCs. For hospitals, only the number of beds was found to be strongly correlated with the peak parking demand. As shown in the table, the relationship between parking demand and the number of beds had a power form. This result is consistent with findings of previous studies (Al-Masaeid et al., 1999). In contrast, peak parking demand for MCCs was found to be strongly correlated with the GFA, number of doctors and number of employees. As such, a separate linear model was developed to estimate parking demand as a function of each independent variable. Moreover, all developed models and their parameter estimates were significant at the 95% confidence level. Finally, investigation of residuals revealed that they were randomly distributed and no outliers were detected.

Table 6. AM peak parking demand (PPD) models/rates for hospitals and MCCs

Land use	Variable	Model equation	R^2	Rate
Hospitals	Number of beds, NB	$PPD=20*NB^{0.6}$	0.76	1.62 space/bed
	GFA, (100 m²)	-	-	1.57 space/100 m²
	Number of doctors	-	-	2.20 space/doctor
	Number of employees	-	-	0.25 space/employee
MCCs	GFA, (100 m²)	PPD=2.88*GFA	0.84	2.90 space/100 m²
	Number of doctors, Dr	PPD=3.45*Dr	0.92	3.44 space/doctor
	Number of employees, E	PPD=1.57*E	0.89	1.55 spaces/employee

DISCUSSION

This study provides a guideline to estimate the AM and PM peak attracted and generated trips and parking demand for hospitals and MCCs. Maximum peaks occurred in the AM periods of workdays for hospitals and on Saturday for MCCs. The developed rates and models would help planners and traffic engineers figure out trips and parking demand based on local conditions rather than using estimates developed for other countries. This issue is very crucial to achieve sound decisions related to the needed geometric or traffic management improvements in the surrounding area and parking requirements within the development itself.

Compared with trip and parking studies conducted in developed countries, this study identifies two major issues. The first one is related to the trip generation and parking demand values. The obtained trip generation value for hospitals in Jordan is larger than that used in the developed countries (ITE, 2012; Douglass and Abley, 2011), but it is approximately equal to the value used in Abu Dhabi, as shown in Table 7. In Jordan, AM peak for hospitals occurred in the period 8:00-9:00, a time during which most patients attend outpatient clinics at the start of the new shift of doctors, nurse staff and employees. On the other hand, trip generation rate for MCCs in Jordan is smaller than that used in the developed countries. Table 7 illustrates that parking demand rates for hospitals and MCCs in Jordan are lower than those of developed countries. This is logical, because developed countries had higher income levels and larger car ownership than Jordan.

Table 7. Comparison of peak trip generation and parking demand rates

Land use	Unit	Study results	ITE	UK	Abu Dhabi
Hospitals	Trip/bed	2.76	1.42	1.53	2.79
	Space/bed	1.62	4.09	2.27	1.49
MCCs	Trip/100 m^2 of GFA	3.39	5.18	5.78	7.05
	Space/100 m^2 of GFA	2.9	4.27	3.01	3.0

The second issue is related to the change in estimates over time as a result of increase in car ownership and size of development in Jordan. For example, Al-Masaeid et al. (1999) conducted a study to estimate parking demand for different land uses, including hospitals, based on data collected in 1997. In a way similar to the results of this study, they found that the power form is suitable to fit parking demand for hospitals. However, the parking demand rate increased from 0.4 in 1997 to 1.62 space/bed in this study. In the 1997 data, the number of beds in hospitals varied from 15 to about 700 beds, while in this study the number of beds varied from nearly 90 to 1100. Furthermore, car ownership was one vehicle for every 15 persons in 1997, while the corresponding figure in this study is one vehicle for every 5 persons. Thus, parking rate in Jordan had increased four times within two decades. As such, trip generation and parking demand should be updated to reflect the impact of car ownership and extent of development changes, specifically for developing middle-income countries such as Jordan.

Also, the results of this study were compared with local parking requirements set by the MoMRA of Jordan. Clearly, these requirements underestimate the needed parking spaces for hospitals by about 30%, when the number of beds is used in computation and overestimate the needed parking spaces by more than 20% when the GFA criterion is used. In the same sense, the MoMRA requirements underestimate the needed parking for MCCs by 45% (according to this study the needed rate is 2.9 space/100 m² of GFA instead of the MoMRA requirements of 2 spaces/100 m² of GFA). Therefore, it is necessary to develop local trip and parking generation based on rational studies rather than on importing external rates or rely on ad-hoc procedures.

Finally, the methodology presented in this study is limited to the land-use developments with well-defined access and parking lots. Furthermore, trip and parking values concluded in this study are applicable to large cities with less transit-oriented areas.

CONCLUSIONS

This study was undertaken to develop models/rates for estimating trip and parking generation of hospitals and medical centers in Jordan. Based on the collected data and analyses carried out in this study, the following can be concluded:

1. The maximum attracted and generated trips and parking demand occurred in the AM period on a typical workday for hospitals and on Saturday for medical centers.
2. Attracted and generated trip rates in the AM and PM were developed according to the major attributes of hospitals and medical clinic centers.
3. Regression models were developed to estimate the AM peak attracted and generated trips. For hospitals, only one model was developed based on the number of beds and the obtained model had a power form. Meanwhile, the attracted or generated trip models for medical clinic centers were found to be linearly related to the GFA, number of doctors and number of employees.
4. Peak parking demand rates/models were developed in this study. The analyses indicated that the relationship between the maximum parking demand and number of beds in hospitals had a power form. At the same time, linear relationships were developed between the maximum parking demand of MCCs and the number of employees, number of doctors or GFA.
5. Compared with trip and parking generation rates for developed countries, the obtained trip and parking generation rates for Jordan had relatively lower values except for trip generation rate for hospitals.
6. Compared with previous studies' results, this study showed that parking demand had increased four folds within two decades. Thus, it is recommended to update parking demand periodically to capture the impact of car ownership and development changes, specifically for developing countries.
7. Finally, it is recommended to establish a local trip and parking generation manual for Jordan to be used by developers and professionals rather than relying on manuals of other countries or studies of limited scales.

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