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VEHICLE PARKING AVAILABILITY IN THE CENTRAL BUSINESS DISTRICT OF IRBID CITY - JORDAN (A CASE STUDY)

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Abstract

Population growth is driving the need to increase the number of parking spaces in crowded cities especially in central business districts (CBDs). A case study was conducted involving different parking location types (Surface parking lots, multi-story building parking, or the on-street parking) to describe the behavior of parkers in the CBD of Irbid city. A parking location demand model was developed to interpret the behavior of parkers in choosing a parking spot. This study includes the development and application of a methodology to develop a demand Multinomial Logit model (MNL) to state the preferences of parkers. SPSS software (Statistical package for the social sciences) was used to analyse the results of a questionnaire-based survey. GIS model builder was utilized to develop a gravity model, so drivers could find the nearest parking location with highest attraction level, based on their preferences, with the shortest route. GIS is a vital tool to propose scenarios for the selection of optimum sites for the construction of an off-street multi-story parking, using the location-allocation algorithm. Results of the analysis revealed that demand is positively related to the walking distance between the parking lot and the parkers' destination and with the parking period in hours. In contrast, demand is negatively related to parking difficulty and purpose of trip.

Keywords: Gravity model, Parkers' preferences, Parking demand model, Parking type, Spatial and geographical analysis.

1. Introduction

When looking for a parking spot in a city's central business district (CBD), an individual has preferences which will influence their decision on where to try and park. The decision will also depend on the availability, location and cost of both on-street and off-street parking (parking lots and multi-story buildings) and will influence the demand for such facilities.

Past studies have tended to focus on some of these factors but not all. For example, considering preferences but not demand in regression models of on-street and off-street parking location, or excluding GIS and spatial analysis. While some factors are specific to the location of the study (e.g.: where to site a new parking lot or garage in a specific city), there are many common variables in the way people choose where to park when visiting a CBD.

Drivers will select a route and a likely location for parking depending on the ease of access and the availability of, and thus the time to find, a parking spot [1-9]. The fee will be influential in the selection [1, 7, 9] with a higher cost per unit time tending to cause shorter times in the spot [10]. Indeed, the fee can influence whether the traveller will drive or use public transit [TR] and can be adjusted to balance demand for curbside versus parkade parking [11].

The purpose of the trip (e.g.: work or shopping) will affect the acceptable walking time from the parking location to the final destination [1, 12] with a significant correlation between walking time and income of the parker [13]. People also have a habit of returning to the same area to park once they have found an area convenient [14]. Interestingly, people tend to discount the cost of fuel and their time when hunting for a parking spot [1]. However, recent technological advances like on-line payment with a smart phone, and information systems similarly available are beginning to influence decisions [15]. Shared parking is seen as risky [16] while shared autonomous vehicles are able to reduce demand because they tend to park farther from the clients' end destinations than if the clients were driving themselves [17].

The location of facilities and their spatial distribution have significant influence on routes taken and thus traffic flow [3, 18-29]. Various modelling techniques have developed to try to understand parking attributes, including mathematical [8, 30, 31] multinomial logit models [12, 32] and mixed multinomial logit models [33].

With respect to Jordan in particular, the demand for residential apartment buildings parking space was assessed by Ghuzlan et al. [31]. The authors developed models, using stepwise regression analysis, to predict the weekday residential building parking demand and identify the significance of different factors from the data collected. They found that the number of apartments and the average apartment car ownership are statistically significant factors in estimating weekday residential building parking demand for all location classes. Average apartment price was a significant factor for suburban, urban non-CBD, and urban inner CBD locations. Building age was a significant factor for suburban and urban outer CBD locations, while the building gross floor area was a significant factor only for urban inner CBD locations.

Al-Masaeid and Bani Hani [34] studied parking characteristics in three zones of Amman, Jordan - Downtown, Jabal Al-Hussien, and Wasfi Al-Tal street. The characteristics included parking duration, trip purpose and tolerable walking distance for both on-street and off-street parking. Downtown parkers were found to park for the longest duration and tolerate longer walking distances to their destinations. Of the Downtown parkers, those on a work-trip tolerated the longest walking distance with an average of about 300 m. Compared with on-street parkers, off-street parkers were willing to walk longer distances to their destinations.

The study described here is focused on the main roads in the CBD area in Irbid, a fast growing governorate in Jordan with an area of about 1572 km^2. Irbid's CBD contains 38 parking lots, and on-street parking distributed over a roughly circular area of 2 km in diameter. The area is straddled by arterial roads. The primary objective here was to develop a demand model to state the preferences of parkers for the main three parking types in Irbid CBD.

Many benefits were expected for the Irbid CBD if the study achieved the objective. These benefits included improving both parking operation and organization of traffic flow on the roads. The consequences would be reduced congestion, queue time and delays with a concomitant reduction in fuel consumption and vehicle emissions together with less travel time along the main road within the CBD area.

2. Methodology

A case study was conducted including different parking location types to describe the behavior of parkers in Irbid CBD, with the objective of determining whether they will use one of three parking options; a surface parking lot, a multi-story parking building, or on-street parking. The choice of the specific type of parking depends on many factors such as walking distance, parking period and parking fees. In this study, the three parking types were compared to estimate which one is preferable to certain types of parkers, depending on their age, gender, residence, monthly income and the purpose of their trip.

It is expected that the results of the study will explore variables that affect parking behavior. Also, recommendations for parking improvement will be suggested. Finally, a recommendation related to the location of a possible multi-story garage building will be suggested based on ArcGIS software. To achieve these objectives, the following tasks were undertaken:

- Examining the previous literature on parkers behavior.
- Identifying the study area.
- Collecting necessary data for developing parking demand and Multinomial Logit models. The required data included age, gender, availability of parking, trip purpose, walking distance, parking fee and monthly income in addition to other variables that may affect the parking demand were collected by distributing 1200 questionnaires over the study area.
- Developing Multinomial logistic parking demand models for the CBD area to assist city planners and engineers to develop an effective parking regulation policy.
- Illustrating the effects of insufficient parking capacity on travellers' choices and defining network flows and areas covered by at least one type of parking location using spatial analyst and network assignments. Figure 1 illustrates the methodology process employed in this study.

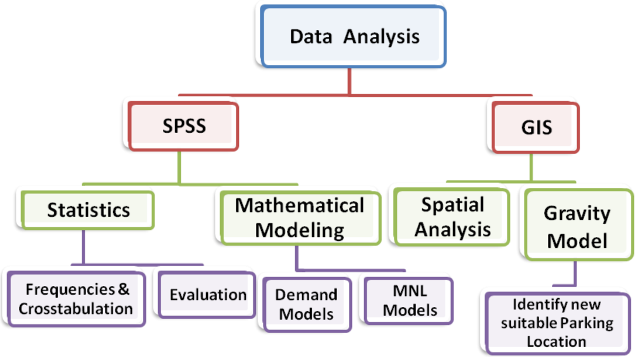

Fig. 1. Flow chart showing the study methodology.

2.1. Field data collection

Parking usage data were collected using a questionnaire interview survey conducted in the study area for 4 weeks (Sunday through Thursday), from 10:00 am until 3:00 pm in addition to an online survey form to raise the sample of completed forms to 1200. The questionnaire for parkers had three parts: characteristics of the parkers, trip and parking information, and evaluation of parking locations. Several factors influenced data collection activities. Some people did not agree to answer the questionnaire, while some others answered only part of the questionnaire: however, the answers of the majority were logical with no contradictions and could easily be explained. After discarding invalid data, 1008 parkers' preference and behavior data forms were utilized.

The data were split into two categories. The first was parking user, which described the behavior and preference of parkers. The second was parking condition, which described the actual state of parking spots. The characteristics of parkers included gender, age, and income. Trip and parking information included the purpose of the trip (job, shopping, recreation, etc.), car ownership, parking location, number of visited places, and parking habits. In order to evaluate the actual behavior of the parkers, parkers were asked to rate the parking space according to several factors like proximity to destination, ease of parking, parking fee, parking duration, and the frequency of usage of a certain parking spot whether it was a parking lot, a multi-story building garage or on-street parking.

2.2. Sampling plan

The sample was selected to be representative of the whole population of Irbid covering all possible demographic and socioeconomic groups. The study area included seven districts surrounding the CBD (Fig. 2). That also shows main and secondary roads of Irbid city as clipped from ArcGIS maps.

As shown the study area is divided into seven districts, with an approximate area of 36.9 km^2 and a population of 316,078 according to the 2016 census conducted by the Jordanian department of statistics.

The sample size was determined using the sample size formula as mentioned in Mohr et al. [35] which included the population size N, the margin of error e, the z-score, and the standard deviation p.

$$\text{Sample size} = 1+\frac{z^2\, p(1-p)}{e^2 N} \tag{1}$$

Given that the population size is approximately 300,000 people with an error margin of 3.1% and a confidence level of 95%, a sample size of 997 people was obtained, and 1,008 were actually surveyed.

The sample weights of each district and their area and population density are presented in Table 1.

Table 1. Districts of studied area with their areas, population density and samples.

District Name	District Area (km^2)	District Population	Density People Per km^2	District Sample	Percentage %
1. Al-Hashemia	1.896	31244	16.48	97	10%
2. Al-Manara	3.578	67928	18.98	109	11%
3. Al-Nasr	4.581	80510	17.57	65	6%
4. Al-Nuzha	5.447	33677	6.18	161	16%
5. Al-Rabieh	6.595	28997	4.40	268	27%
6. Al-Rawdah	6.915	34436	4.98	183	18%
7. Al-Barha	7.867	39286	4.99	125	12%

At the interview, each parker was requested to answer several questions about their personal socio-demographic characteristics, parking information and finally their evaluation of the parking process. These characteristics and the associated categories are listed in Table 2.

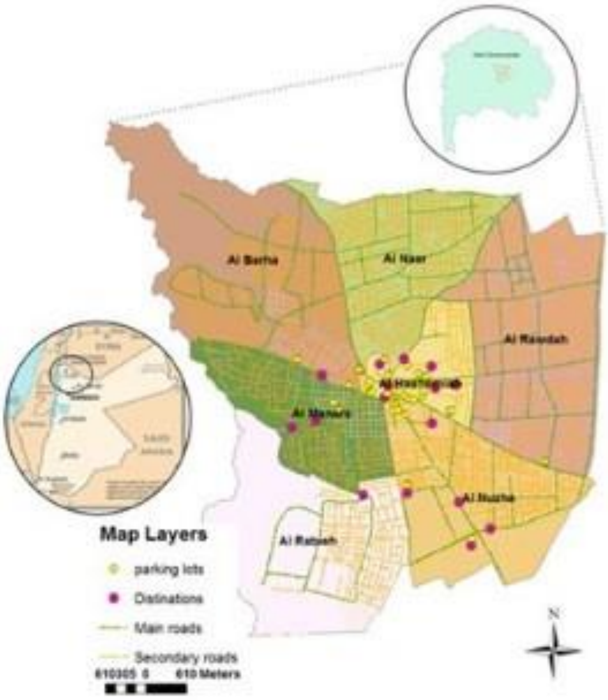

Fig. 2. Study area layout showing Irbid CBD and surrounding districts as clipped from ArcGIS maps version 10.4.1.

Table 2. Socio-demographic, trip information and evaluation of the parking categories.

Characteristic	Categories				
Gender	Male	Female			
Age (year)	< 20	21-30	31-40	41-50	> 50
Monthly income (JD)	<300	300-500	500-750	750-1000	>1000
Residence place	Urban	Suburban	Rural		
Vehicle ownership	Owned	Not Owned			
Purpose of trip	Shopping	Work	Recreation	Other	
Walking distance (m)	< 50	50-150	150-200	200-400	
Parking period (hr)	1	2	3	4	>5
Fee (JD)	0	1	>1		
No. of visited places	1	2	3	4	5
Frequency of using certain parking location	1	2	3	4	5
Parking type	Parking lot	Building parking	On-street parking		
Time of parking	Morning peak	Evening peak	Otherwise		

2.3. Study limitations

This type of traffic engineering study is expected to have many limitations. First, the study was conducted to determine the level of peoples' preferences to use certain parking locations according to certain parameters. A second limitation faced by the study is that Irbid city is not well planned, and parking locations are random, demanding extra work when analysing each district when applying the gravity model. Third, this study was conducted in a limited geographical area within Irbid (the CBD area and surroundings).

Also, the sample size was constrained to those who were willing to complete the survey and individuals who were able to access the survey online and fill it in accurately. About 175 survey forms were distributed online but not all of them were answered completely therefore 200 questionnaires Approximately were excluded before the data were analysed to get the final 1008.

2.4. Study area

The choice of the study area was delineated by considering the availability of different types of parking locations. A roughly circular area of about 2-km diameter in the city CBD area was selected. The clock tower roundabout is located at the center of this area. To be useful the study area had to have at least one multi-story building (Garage), one surface parking (lot) and one on-street parking location. These qualifications led to the choice of the seven districts surrounding Irbid central business district (Fig. 1) and shown in Table 1.

The questionnaire counts and distribution as shown in Table 1 were proportioned to the area and population of each district, so the 1008 sample was distributed as follows, Al-Hashemia 97 (10% of the sample size), Al-Manara 109 (11%), Al Nasr 65(6%), Al-Nuzha 161(16%), Al-Rabieh 268 (27%), Al-Rawdah 183 (18%) and Al-Barha 125 (12%). The actual state of the evaluated parking places was observed and was utilized to verify the validity of the parking behavior data.

The SPSS software was utilized to obtain statistics and frequencies for the population of each district, with percentages of their age, gender, residence place, monthly income, purpose of trip, walking distance, parking type, parking period, car ownership, number of visited places, and finally morning and evening peaks. Furthermore, SPSS gives the ability to find the correlation between all parameters as crosstabulation, not only the relation between the dependent and independent variables but also between independent variables as pairs, in addition to the employment of one-way ANOVA. The significant factors that may affect parking demand when modeling are listed in Table 3.

Table 3. Significant factors affecting the parking demand as analysed using IBM SPSS 25.

Q[Lot]	Q[Building]	Q[Street]
Age (P=0.013)	Income (P=0.000)	Age (P=0.014)
Income (P=0.013)	No. of visited places (P=0.006)	Income (P=0.034)
Fee (P=0.007)	Walking Distance (P=0.001)	Car ownership (P= 0.037)
No. of visited places (P=0.032)		

Significance levels (P-value) in parenthesis indicate the effect of each of the corresponding factor on each parking demand type using One-way ANOVA.

Geographic Information System (GIS) software was utilized to model and analyse the problem of urban parking planning. The problem is defined as a localized resource allocation (LRA) problem. Indeed, the solution to a particular urban configuration implies the assignment of a set of parking lots (the resources) to the drivers (the parkers). In addition to the problem specification, we were interested in proposing an efficient solution to the parking problem in the Irbid CBD, by proposing more than one scenario for the optimum site selection of an off-street parking garage using the location-allocation algorithm and the Gravity Model (Huff Model) which are supported by the GIS software.

3.Results and Discussion

First, the survey data were analysed and are presented in tables comparing the effect of the parameters on the demand of parking types in Irbid CBD. Second, the modeling steps to get the parking demand binary Logit model are summarized with all factors that identified the parkers' preferences to use "on-street" or "off-street" parking locations. Lastly, the spatial and geographical analyses utilizing the GIS software are discussed: the gravity model was implemented by dividing the study area into polygons to find the probabilities of attractiveness of "off-street parking" and the best routes between parkers' origins and destinations were assessed.

3.1. Parkers' preferences

Analysis of the data indicated that 151 (15%) of the total sample chose the multi-story building parking, 351 (35%) used surface parking lots and 506 (50%) used on-street parking. This is because most of the people who were interviewed and who were working in the CBD would like to park their vehicle in front of their offices or markets - they rarely use off-street parking.

The results of the study are shown in Table 4.

Table 4. Socio-Demographic characteristics, evaluation of the parking location results, trip and parkers characteristics of survey sample.

Socio-Demographic characteristics			**Evaluation of the parking location results**			**Trip and parkers characteristics**		
Characteristic	**Count**	**Percent %**	**Characteristic**	**Count**	**Percent %**	**Characteristic**	**Count**	**Percent %**
Age:			**Location of parking place**			**Parking type**		
<20	39	3.9%	Suitable	693	68.8%	Parking lot	351	34.8%
21-30	444	44%	Moderate	102	10.1%	Building parking	151	15%
31-40	275	27.3%	Not suitable	213	21.1%	On-street parking	506	50.2%
41-50	154	15.3%						
> 50	96	9.5%						
Gender:			**Closeness to destination**			**Purpose of trip**		
Male	878	87.1%	Close	811	68.8%	Work	749	74.3%
Female	130	12.9%	Moderate	126	10.1%	Shopping	117	11.6%
			Far	71	21.1%	Recreation	50	5%
						Other	92	9.1%
Monthly income:			**Ease to park**			**Parking Fee(JD)**		
< 300	356	35.5%	Easy	468	46.4%	0	775	76.8%
300-500	448	44.4%	Moderate	145	14.4%	1	229	22.7%
500-750	113	11.2%	Difficult	395	39.1%	>1	4	0.4%
750-1000	61	6.1%						
>1000	30	3%						
Residence place:						**Vehicle Ownership**		
Rural	68	6.80%				Owned	868	86.2%
Suburban	237	23.50%				Not owned	139	13.9%
Urban	703	69.70%						

No. of visited places 1 2 3 4 5	594 148 149 45 72	58.9 % 14.7 % 14.8 % 4.5% 7.1%
Walking distance (m) <50 50-150 150-200 200-400	597 237 89 85	59.2 % 23.5 % 8.8% 8.4%
Parking period (hr) 1 2 3 4 5 6	70 62 67 45 114 650	6.9% 6.2% 6.6% 4.5% 11.3 % 64.5 %
Time of parking Morning peak Evening peak	753 511	74.7 % 50.7 %

Following are the results and discussion of several survey data according to the statistics. A summary of the results is shown in Table 5.

Table 5. Results of parking type preferences crosstabulations as analysed using IBM SPSS 25.

Characteristic	Categories	Parking type			Total
		Building	on-street	Parking lot	
Age	<20	0.8%	1.7%	1.4%	3.9%
	21- 30	7.0%	21.7%	15.3%	44.0%
	31- 40	3.8%	15.3%	8.2%	27.3%
	41- 50	2.4%	6.6%	6.2%	15.3%
	>50	1.0%	4.9%	3.7%	9.5%
	Total	15.0%	50.2%	34.8%	100.0%
Gender	Female	1.8%	7.0%	4.1%	12.9%
	Male	13.2%	43.2%	30.8%	87.1%

	Total	15.0%	50.2%	34.8%	100.0%
Residence	Rural	1.20%	2.10%	3.50%	6.80%
	Suburban	5.80%	4.60%	13.10%	23.50%
	Urban	8.00%	43.50%	18.20%	69.70%
	Total	15.00%	50.20%	34.80%	100.00%
Trip purpose	Work	12.50%	31.80%	30.00%	74.30%
	Shopping	1.30%	9.00%	1.30%	11.60%
	Recreation	0.50%	2.50%	2.10%	5.10%
	Other	0.70%	7.00%	1.40%	9.10%
	Total	15.0%	50.2%	34.8%	100.0%
Number of visited places	1	9.0%	30.4%	19.6%	59.0%
	2	2.3%	6.9%	5.5%	14.6%
	3	1.8%	7.8%	5.2%	14.8%
	4	0.5%	2.4%	1.6%	4.5%
	5	1.4%	2.8%	3.0%	7.1%
	Total	15.0%	50.2%	34.8%	100.0%
Parking fee (JD)	0	14.68%	48.21%	13.99%	76.88%
	1	0.30%	0.50%	21.92%	22.72%
	>1	0.00%	0.00%	0.40%	0.40%
	Total	15.0%	50.2%	34.8%	100.0%
Walking distance (m)	<50	14.98%	34.82%	9.42%	59.23%
	50-150	0.00%	8.04%	15.48%	23.51%
	150-200	0.00%	1.29%	7.54%	8.83%
	200-400	0.00%	6.05%	2.38%	8.43%
	Total	15.0%	50.2%	34.8%	100.0%

3.1.1. Purpose of trip

As may be seen in Table 5, the purpose of most of the surveyed parkers was "working trips", with a percentage of 74.3%. This indicates that most of the CBD area parking users are the market, restaurant and office owners, while the parkers who come for shopping, recreation or other purposes constitute the rest at 25.7%. Therefore, the parking problem is basically created by work place owners, which is logical because the trip purpose is related directly to parking period, and parkers who come for work tend to use the parking location for longer times in comparison with other trip purpose parkers.

The parkers' preference to use the on-street parking was as follows 31.8%, 9%, 2.5% and 7% for the "work", "shopping", "recreation" and "other" purpose categories, respectively (see Table 5). This means that most people park their vehicles on-street all day, because the work category represents the largest group in the sample. Thus, the first cause of the parking problem in the Irbid CBD area is identified.

3.1.2. Walking distance

Walking distance came in four categories as shown in Table 5. The highest proportion was the "<50 meters" walking distance, with a score of approximately 60%, and is a result of the tendency of the parkers to use on-street parking places located in front of their workplace, so they could walk minimum distance available every day. As shown in Table 5, all "multi-story building parking" users walk less than 50 m and approximately 70% of the “on-street parking” users walk less than 50 m, while approximately half of the "parking lot" users walk between "50-150 m".

3.1.3. Parking fee

The pricing system for parking lots in Irbid city is 0.5 JD per hour, but parkers who participate in a certain parking lot pay between 25-30 JD monthly, which equals 1 JD or less per day. The parking fee was therefore classified as "0 JD", "1 JD" and "more than 1 JD" per day. 77% of the parkers interviewed said that they do not pay while parking. This is because half of the parkers surveyed use on-street parking, and 15% use multi-story building parking which is free in Irbid, in addition to some parkers who use their companies and workplace parking lots or the parking spaces that belong to the government departments they are working for. For instance, it was found that about 22% of the on-street parkers pay 1 JD while less than 1% of them pay more than 1 JD.

3.1.4. Number of visited places

As may be seen from Table 5, 59% of people tend to visit one place only while parking their vehicles: for example, people who come to the CBD area for "work" only visit their workplace. On the other hand, people who come for shopping, recreation or other purposes would visit two, three, or more locations while parking, such as markets, restaurants, banks or even medical clinics.

3.1.5. Age

The parking type levels for the age categories: "<20"," 21-30", "31-40", "41-50', ">51 years" were 3.9%, 44.0%, 27.3%, 15.3% and 9.5% respectively. The youngest drivers (<20 years old) had the lowest preference level for multi-story building parking. With older individuals (21-30), the level of preference jumps to 44% and the highest preference level of on-street parking goes to the same age group, see Table 5.

3.1.6. Gender

The “female” category was very small (130 (12.9%) of the 1008 completed surveys) because of the low number of women drivers in Irbid city. In addition, there were some females who refused to answer the questionnaire. However, it was noticed that their preferences to building parking and surface lots were very close. On the other hand, male drivers tended to use on-street parking with a percentage of 43%.

3.1.7. Place of Residence

The preference of parking type for people who live in urban areas is on-street, in contrast to the preference of people who live in suburban areas which is off-street parking (lots and building garages). The percentages of visitors from rural places is low compared to those from suburban or urban places.

3.2. Parking demand binary logistic modeling

The correlations between parking demand and the parameters studied were analysed with Microsoft Excel and entered into the SPSS program to obtain the multinomial Logit model described below. There are four factors affecting the parking demand in Irbid CBD (Table 6). They are the parkers' purpose of trip, their walking distance from the parking location to their destination, the parking period and the ease of the parking process.

Table 6. Variables in the equation with their coefficients and their significance as analysed using IBM SPSS 25.

Variables in the Equation	B	S.E.	Wald	Sig.	OR
Purpose of trip	- 1.964	0.097	11.571	0.007	0.140
Walking distance	3.388	0.131	5.477	0.000	29.607
Ease to park	- 0.974	0.129	9.812	0.001	0.3775
Parking period	0.793	0.203	0.227	0.005	2.210
Constant	21.203	0.456	0.508	0.051	

Since the model is logistic which depends on binary dependent variables (0,1) the parking types should be classified as two categories, so the SPSS software can process them. Therefore, the multi-story building parking (15%) and the surface parking (34.8%) lot were merged into one category as "off-street parking" (49.8). Then the proportion of parkers who prefer to use on-street parking were expressed as P (where P is a number "probability" between 0 and 1) and those who use off-street were expressed as (1-P) or Q , the final model is as follows:

$$\text{probability} = \frac{1}{e^{u}+1} \tag{2}$$

where;

$$U = 3.388\,X_1 + 0.793\,X_2 - 0.974\,X_3 - 1.964\,X_4 + 21.203 \tag{3}$$

After some algebra, the final model is:

$$P = \frac{1}{1 + e^{3.388\,X1 + 0.793\,X2 - 0.974\,X3 - 1.964\,X4 + 21.203}} \tag{4}$$

where,

P = Dependent variable represents the probability on off-street parking, where off-street is represented by 1 and on-street by 0.

X_1 = Walking distance in meters

X_2 = Parking period in hours

X_3 = Ease to park (Ranking as difficulty level 1, 2, 3)

X_4 = Purpose of trip, where the work based trips are represented by 1 and non-work based by 0.

U = summation of all independent variables included in the model

It was noticed that the demand is positively proportioned with the walking distance between the parking lot and the parkers' destination and also positively proportioned with parking period in hours.

Parameter Estimate (B): These are the regression coefficients. The predicted probability of using a certain parking location can be calculated using these coefficients. Note that two of the coefficients are positively related with the demand

and the other two are negatively related. A positive coefficient indicates that when the predictor increases, so does the expected likelihood. A negative coefficient indicates that as the predictor is increased, the projected preference or likelihood decreases. The coefficient, the bottom number in the column, is the model's constant term.

Interpretation of the coefficients in the Logit regression is not as easy as it is in linear regression. The increase in probability attributed to a one unit increase in a given parameter estimate means an increase of exp^(beta value) according to the odd ratio Exp(B) in the last column. As an example, the 0.793 increase in the parking period makes an increase of (e^0.793) which gives a 2.210 times increase in the demand model. Individual regression coefficients can be interpreted in a limited number of ways.

Std. Error (S.E): These are the individual regression coefficients' standard errors. They are utilized to calculate the Wald test statistics (Table 6) and the confidence interval of the regression coefficient.

Wald: These are the test statistics (squared ratio of regression coefficient Estimate to Std. Error of respective predictor) for the individual regression coefficients. The test statistic has a Chi-Square distribution and Wald test is always greater than the likelihood ratio test.

Significance (Sig.): These are the p-values of the coefficients, or the probability of the null hypothesis that the regression coefficient of a particular predictor is zero if the remaining predictors are in the model. They are based on the predictor's Wald test statistics. The probability that a particular Wald test statistic is as extreme as that observed under the null hypothesis is defined by the P-value shown here.

The purpose of trip was forced to enter the model, by reclassifying its categories: at first it was classified as 4 groups; "work", "shopping", "recreation" and "other" purposes as mentioned in Table 5 above. However, since the work category formed more than 70% of the sample size, the other three trip purposes were pooled into one category named "non-work", after the new classification, the P-value was 0.027 which is considered significant as it is < 0.05.

Table 7 shows the tests that measure the goodness of fit for the Logit model. The common tests are the Cox & Snell *R* Square and the Nagelkerke R^2, which are pseudo *R* squared values use to assess the fit of logistic models. They are calculated by SPSS software to be 0.538 and 0.720 respectively. The (0.720) R^2 means that the model could explain 72% of the variation of the data analysed. These *R* squared values indicate a good model since Nagelkerke R^2 test used is higher than Cox & Snell R^2.'

Table 7. Model summary showing goodness of fit tests results as analysed using IBM SPSS 25.

Model	-2 Log likelihood	Cox & Snell *R* square	Nagelkerke *R* square	Hosmer and Lemeshow Chi-square
1	29.537	0.538	0.720	0.996

- 2 Log Likelihood: This is the product of -2 and the log-likelihood of the null model and fitted model. The Model likelihood is used to test if the regression coefficients of all predictors in the model are zero at the same time, and to test nested models. In this model log likelihood is = 29.537, which indicates a good model.

Chi-Square: This is the Likelihood Ratio (LR) Chi-Square test that determines whether at least one of the regression coefficients of predictors in the model is not equal to zero

Hosmer and Lemeshow Chi-square: from the above table (Table 7) note that H&L chi square with P = 0.996 that is > 0.5 indicating that it is a good model.

The correlation matrix for the four factors included in the mathematical model is presented in Table 8.

Table 8. Correlation matrix for the four factors included in the mathematical model as resulted from IBM SPSS 25.

Correlation matrix		Ease to park	Parking period (hr)	Purpose of trip	Walking distance (m)
Ease to park	Pearson correlation	1	-0.233-**	-0.440-	-0.240-
	Sig. (2-tailed)		0.415	0.223	0.911
	N	1008	1008	1008	1008
Parking period (hr)	Pearson correlation	-0.233-**	1	-.353-**	-0.511-
	Sig. (2-tailed)	0.415		0.430	0.736
	N	1008	1008	1008	1008
Purpose of trip	Pearson correlation	-0.440-	-0.353-**	1	0.366*
	Sig. (2-tailed)	0.223	0.430		0.343
	N	1008	1008	1008	1008
Walking distance (m)	Pearson correlation	-0.240-	-0.511-	0.366*	1
	Sig. (2-tailed)	0.911	0.736	0.343	
	N	1008	1008	1008	1008

According to Figs 3 through 5, assuming a walking distance of 50 m and an easy difficulty parking level, the probability of choosing off-street parking varied among different trip purposes. As shown in Fig. 3, it can be noticed that the probability of preferring off-street parking increases with increasing the parking period. For instance, let us take 6 parking hours and see the behavior of both workers and non-workers: about 17% of worker drivers tend to use off-street parking which means that 83% of them use on-street parking, while about 75% of the non-worker drivers tend to park off-street.

As shown in Fig. 4, at 50 m walking distance and "work" trip purpose, the probability of utilizing off-street parking varied with the parking period. As may be seen, the probability of selecting off-street parking is higher for drivers with a hard difficulty level of parking. For example, less than 10% of drivers with easy parking tend to use off-street parking, 29% of drivers with medium level of parking difficulty tend to use off-street parking, while about 85% of drivers with who find it difficult to park use off-street parking which means an existence of a real problem with parking lots especially with searching time and walking distance.

From Fig. 5 it is noticed that with a "work" trip purpose and an easy parking level, 9% of the parkers with short walking distance at 6 hours parking period tend to use off-street parking while 65% of parkers who walked long distances tend to use off-street parking.

As shown in Fig. 6, for parkers who come for a work-based trip and for a given parking period, the probability of utilizing off-street parking varied with the walking distance. The probability of choosing off-street parking is larger for drivers who park for shorter periods. From Fig. 6, about 90% of drivers with 1-hr parking duration tend to use off-street parking because they prefer to use a parking lot with a fee rather than waste time searching for parking on-street, 30% of drivers with 3-hr (moderate) parking duration tend to use off-street parking, while less than 10% of drivers with long parking duration (6 hours or more) use off-street parking.

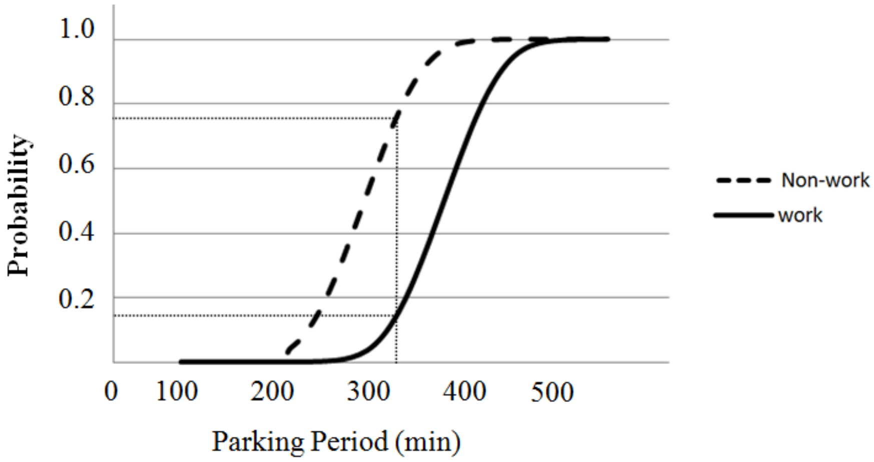

Fig. 3. Probability of choosing off-street parking for different trip purposes.

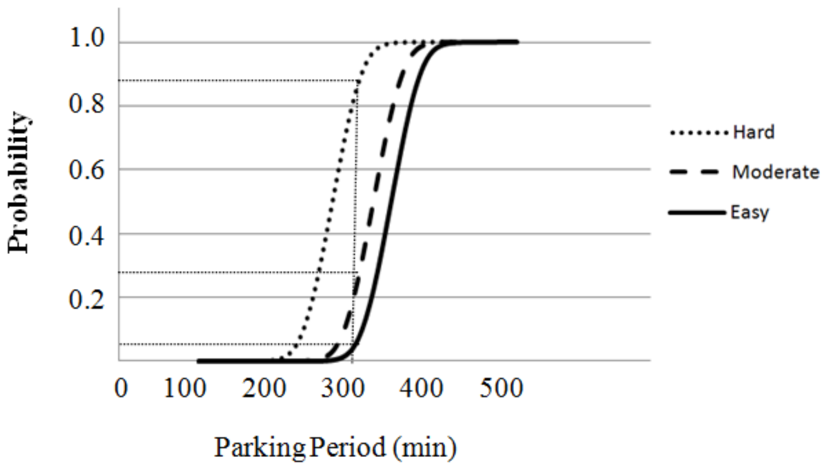

Fig. 4. Probability of choosing off-street parking for different parking difficulty levels.

These results may show some contradiction because it is logical that with an increase in parking duration, the tendency to use off-street parking increases, but in this case the opposite scenario happened. The reason for this contradiction lies with the parkers with "work" purpose of trip category. According to the statistics, more than 70% of the whole sample is people who work at the CBD area. Most of them tend to use a specific location on-street and also tend to use this parking location for more than 6 hours. Finding a solution for this issue may positively affect the parking condition in the Irbid CBD. Convincing these market and office owners to use off-street parking will definitely enhance the parking circumstances by increasing vehicle turnover rates.

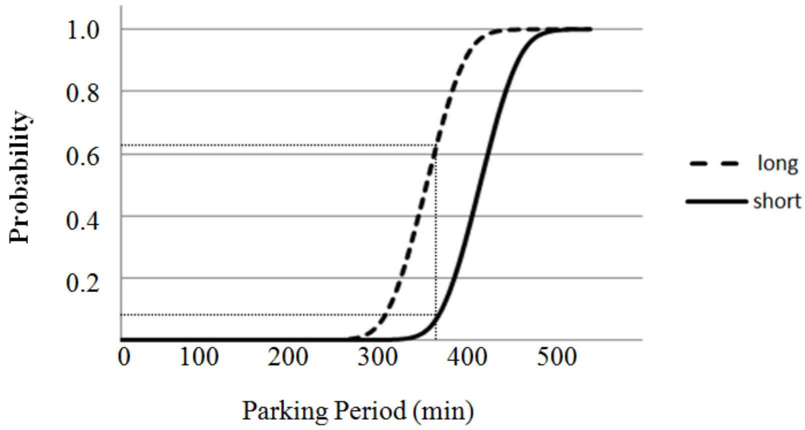

Fig. 5. Probability of choosing off-street parking for parking walking distance.

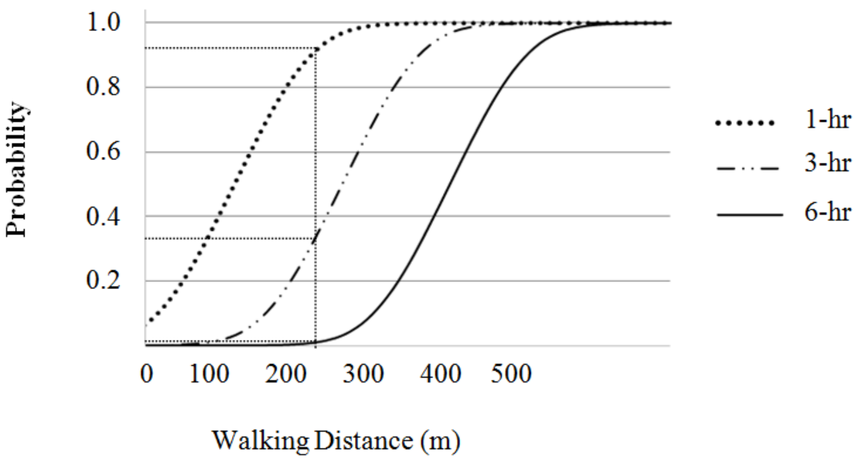

Fig. 6. Probability of choosing off-street parking for different parking periods.

3.3. Spatial and geographical analysis

First, the study area was divided into seven known districts (Al Rabieh, Al Nuzha, Al Hashemia, Al Nasr, Al Rawdah, Al Barha and Al Manarah). Each district has its own characteristics, and these characteristics are the population, the area, the population density and trip attraction locations in each district. While there are two main types of parking (off-street and on-street), this study considered the distribution of the parking lots for off-street parking, and the lane availability for on-street parking.

The distribution of the parking lots is obtained by X, Y coordinates pinned on Google maps for each parking lot in the study area by using "share location", to make a network of the lots in each district. After that, the capacity of each parking lot was defined manually in addition to the time of day/week when the lots are fully occupied. This information was collected by interviewing the valet men at the 38 parking lots studied, depending on the characteristics of the parking lots, mainly their capacity. Catchment areas were drawn using ArcGIS shapefiles for each lot to find the serviced area and un-serviced areas and areas of overlap.

There is also another way to find the areas that each off-street parking lot services or covers: that is the Thiessen polygon which is a tool created by ArcGIS. Each Thiessen polygon has only one point entry feature (the parking lot). Any location within a Thiessen polygon is closer to the point associated with it than any other point entry feature. These polygons or proximal zones are triangulated into an irregular network (TIN); Perpendicular bisectors are created for each edge of a triangle, forming the edges of Thiessen's polygons. The locations where the bisectors intersect determine the locations of the vertices of the Thiessen polygon. Thiessen polygons are designed to create a polygon topology, (ESRI 2014).

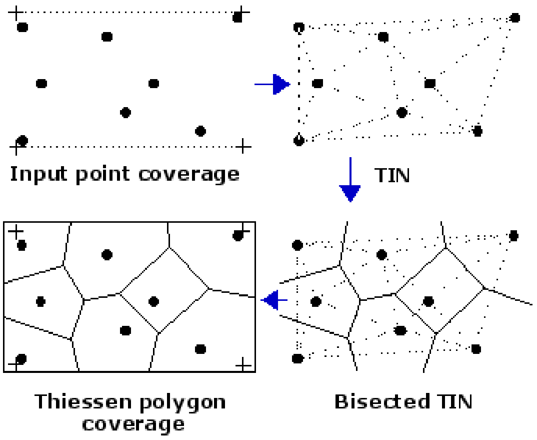

Fig. 7. Creating Thiessen polygon from points as extracted from ArcMap program (ArcGIS version 10.4.1).

Thiessen Polygons (Figs 7 and 8) are generated using the point feature class, where a polygon with only one point entry feature is created. Any location within this polygon is closer to that point than any other point in the input feature. This tool was used to divide the area of Irbid CBD into many polygons. These polygons represent the area of service for each individual parking lot. The tracts with centroids contained within each Thiessen polygon were then summed by population, multiplied by 100 and divided by the total population of the seven districts to achieve a percentage of the total attraction.

This method does not take into account any time variable that may draw parkers to a specific lot that is closer to the desired destination. This method makes estimations based on an assumption that the majority of the population demands the lot area closest to them only.

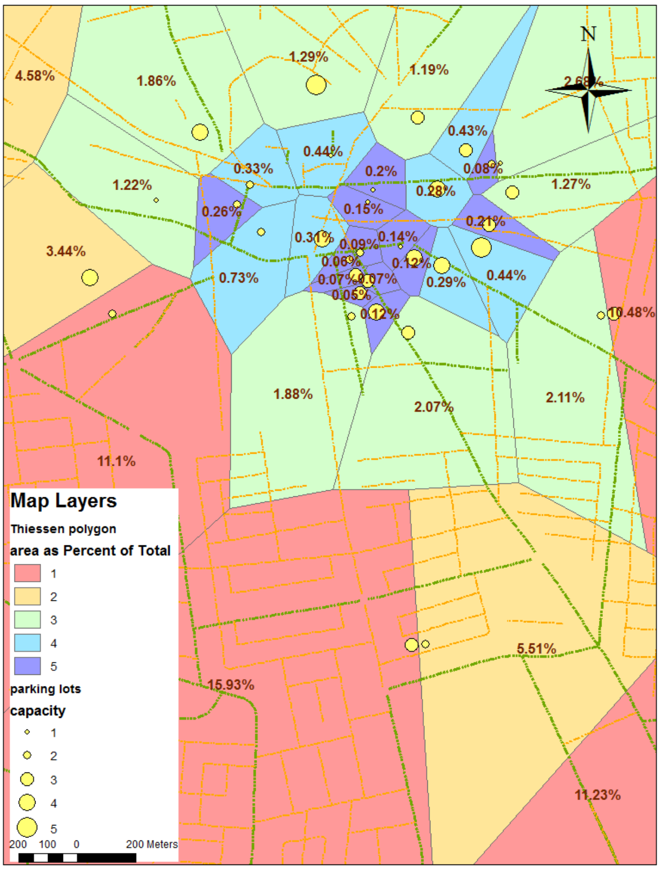

Fig. 8. Creating Thiessen polygon from Parking lot points as drawn by ArcMap program (ArcGIS version 10.4.1).

The last step in the study was to evaluate the best place to construct a multi-story parking building that will have equal capabilities for all users and be reachable for most of the parkers heading to CBD area. The location is based on the location-allocation algorithm and Optimum site selection (OSS) to reduce the fuel consumption and to obtain the minimum travel and search time. The Gravity Model is applied here which is a model in urban geography derived from Newton's law of gravity. This model is used to predict the degree of interaction between two locations (Rodrigue et al. [36], 216) depending on a mathematical formula that includes the spatial interaction between the origin and the destination in addition to their population density (see Fig. 9).

The level of interaction between two locations is a function of their attributes in association with their level of separation. Separation is usually squared to reflect the increasing friction of distance. In Fig. 9, two locations (i and j) have a respective "weight" (population density) of, for example, 45 and 20, and are at a distance (degree of separation) of 10. The resulting interaction is 9. According to this formula, the general formulation of spatial interactions can be adapted to reflect this basic assumption to form the elementary formulation of the gravity model (GM):

$$T_{ij} = k\frac{P_i P_j}{d_{ij}} \quad (5)$$

where

T_{ij} : Level of attraction between origin i and destination j

P_i and P_j are significance of locations of origin and destination, respectively.

d_{ij} is the distance between the locations of origin and destination.

k is a constant proportional to the event rate. For example, if the same system of spatial interactions is considered, then the k value will be higher if the interactions are considered for a year than the k value for one week.

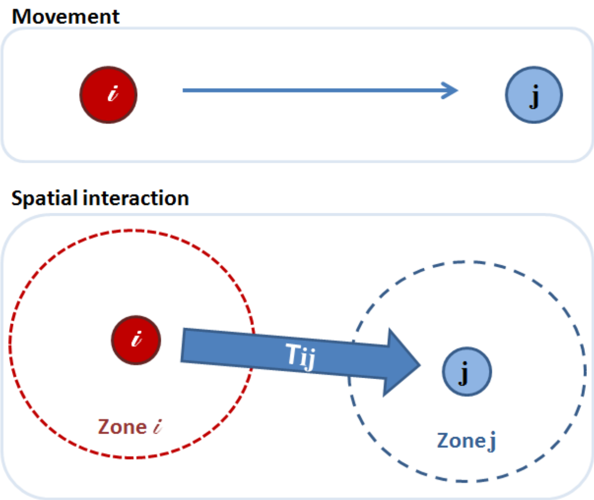

Fig. 9. Gravity model main factors (distance and population) as used in ArcMap program (ArcGIS version 10.4.1).

Knowing the areas of trip attraction in the city and the distribution of the parking lots and their catchment areas, a parking location network could be enhanced with concentration on trip attraction and generation areas by increasing multi-story parking. Such an addition will reduce the demand on on-street parking, especially in hot spots which are involved in risky situations and fatal accidents.

The following map (Fig. 10) uses a quantitative graduated colours symbology as an example for a particular parking lot. The highest probability or attraction rate is at the parking lot that the driver chooses, which is expressed as the darker colour of symbology. The probabilities then start to decrease according to distance and population density at each parking location. This geographical illustration of the gravity model recommends the second best parking lot available given its capacity and closeness to the chosen parking lot, and if the second recommended lot was also fully occupied then the model gives a third recommendation, and so on.

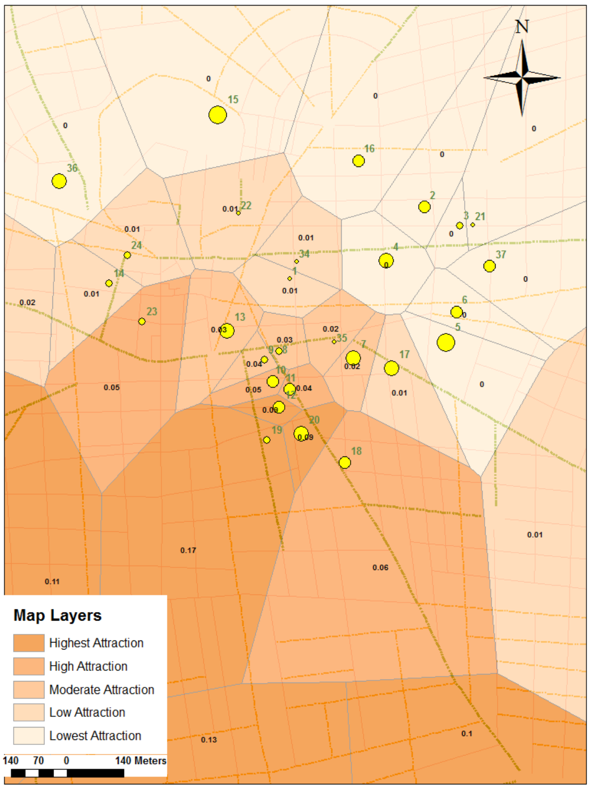

Fig. 10. The Gravity model applied on Thiessen polygons according to parking no.19 as drawn by ArcMap program (ArcGIS version 10.4.1).

To evaluate the best location to construct a multi-story building garage with a very high capacity to supply the whole surrounding area, the coverage area of all 38 parking lots studied should be known. This coverage area results from the union of the buffer areas drawn around each parking lot. These buffer areas represent the most probable walking distance that the parkers could walk to his or her destination, which was 200 m according to the survey statistics. After that, a polygon containing the area where no on-street parking is permitted is drawn. Then the layer resulted from clipping the buffer zone from the polygon is considered as the "un-serviced area". This area where no "on-street" or "off-street" parking is available, is the area where the new building garage should be constructed.

According to many studies, the evaluation of the optimum site selection for a parking location depends on certain parameters. The garage entrance should be on the street with the traffic flow, and it should have an exit to ease the process of vehicle turnover and circulation. The street should not have a high speed limit such as highway or freeway. Also, the area of the project should be open and flat, the location of the parking has to be reachable for all drivers, with equal capabilities, and if it is closer to the center of the CBD that would be more efficient.

All these steps are applied using ArcGIS and demonstrated as maps. After taking into consideration all the factors mentioned above, there were seven recommended locations. These locations are shown in green symbols on the map in Fig. 11.

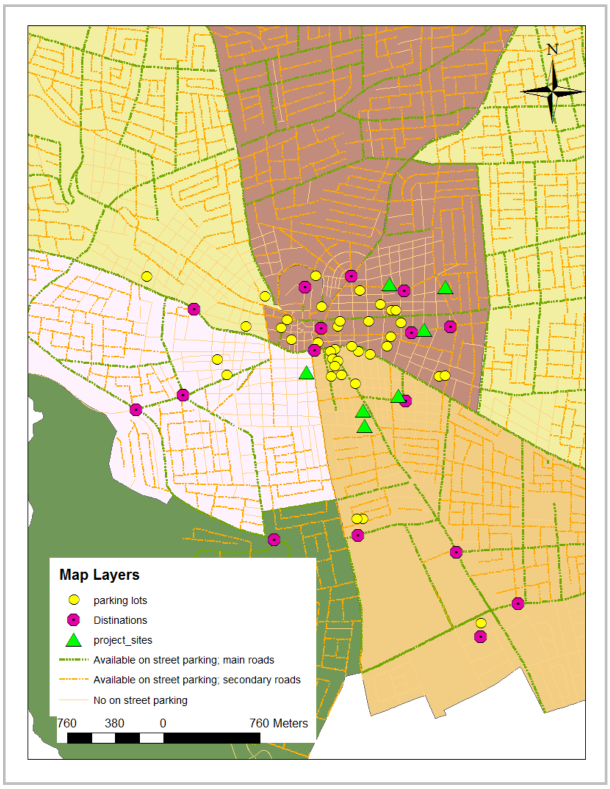

Fig. 11. The recommended sites -in green- for the multi-story building project as drawn by ArcMap program (ArcGIS version 10.4.1).

The procedure for selecting the best site for the construction of a multi-story car park in the central business district of Irbid city includes studying decision information, specifying the criteria preferences (mentioned above), and determining the individual and group rankings of decision alternatives.

Routes between origins and destinations are also studied using ArcGIS network analyst. Assuming that the parker's current location is their origin and the parking lot they are heading for is their destination, then the analyst is a vital tool to recommend the best and shortest path between the two points. By constructing a road network with a junction on every vertex on the road, the next step is to identify the parker location and the desired parking lot. ArcGIS solves for the shortest possible path with shortest time if using ArcGIS online.

Another facility is provided by the software, which gives more than one alternative for each route, this means that if there was any barrier or obstacle on route number one, this barrier could be a stop sign, detour sign or work zone sign, then the software gives the driver a second and a third and many more recommended alternatives to reach their destination within the shortest time. See Figs 12 and 13.

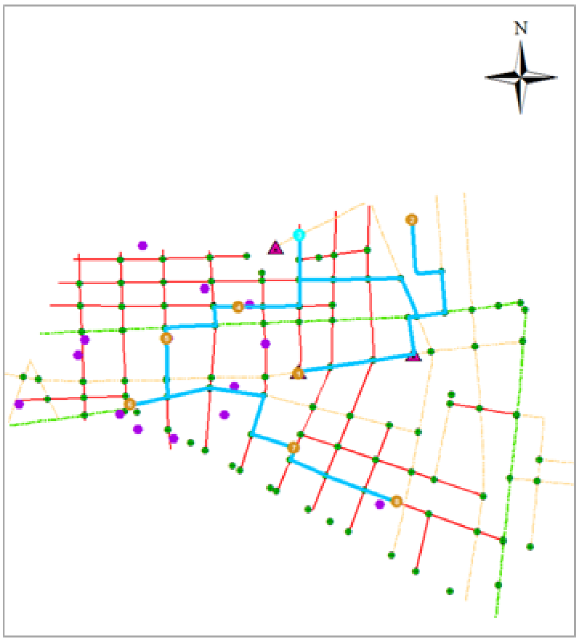

Fig. 12. Region from the study area showing eight examples of shortest routes leading to eight different destinations as extracted from ArcMap program (ArcGIS version 10.4.1)

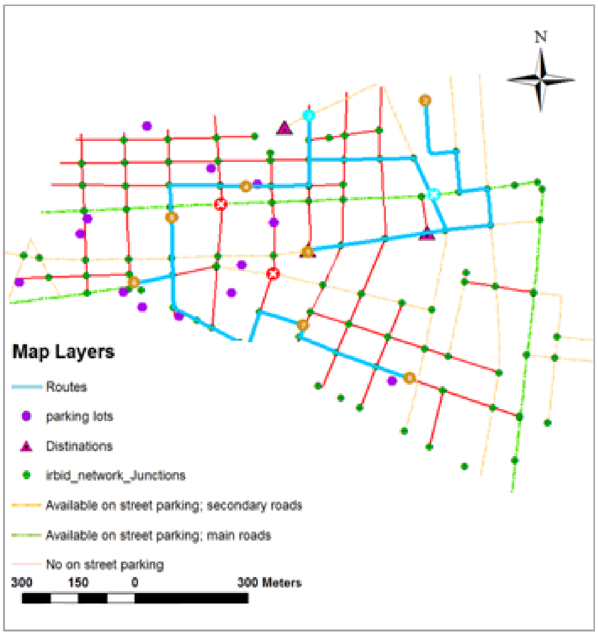

Fig. 13. Solving for alternative routes after adding road barriers (restrictions) as extracted from ArcMap program (ArcGIS version 10.4.1).

4. Conclusions and Recommendations

Based on the analysis made in this study, the following points were concluded:

- Younger parkers and female parkers prefer "on-street" as place to park whereas older parkers treat the three kinds of parking places nearly identical.
- People who live in urban areas tend to use on-street parking while people coming from suburban areas used mostly off-street parking (lots and building garages).
- Number of visited places also affected the parking choice: with an increasing number of places to visit while parking the vehicle, the preference to use "off-street parking" increase especially the "surface lots".
- Parking period affected the preference of parking so the tendency to use "off-street parking" was higher with increasing parking duration.
- The developed MNL regression model find that demand is positively proportioned with the walking distance between the parking lot and the parkers' destination and with the parking period in hours. And negatively proportioned with parking difficulty and purpose of trip.

Recommendations according to the results:

- It is recommended to expand this research by using larger samples and include different areas in Irbid, not just at the CBD area, so that the study could develop a model that is applicable to the whole governorate. In addition, it is recommended to study traffic flow rates in the morning and evening peaks at each road and the number of vehicles the roads can accommodate. Furthermore, it is recommended to study the location of traffic signals on the main roads as they affect the speed and the density of the traffic movement. All these factors affect the parking demand at the CBD.
- During field data collection and from researchers' notes, it was noted that some parking lots need maintenance and more than one entrance (an entrance and an exit) to ease the movement of the vehicles in and out of the lot, especially in lots that are located on one way direction roads.
- It is noted also that a high percent of parking problem and traffic congestion is a result of passenger cars not being fully occupied, so car-pooling and ride sharing are highly recommended. This recommendation applies especially to the companies or the business centres in the critical CBD areas, as these companies can offer a van or a bus for their employees to make more than one trip per hour (in the morning and afternoon) to pick them up, which would reduce the parking problem.
- Finally, the construction of multi-story building parking is recommended to reduce the demand on surface lots and thereby dispense with many of them in order to replace them with green areas and landscaping to enhance the CBD environment and improve its ecological conditions.

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