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GIS Potential in Parking Lots Studies

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ABSTRACT

The main objectives of this work were to investigate the potential of utilizing Geographic Information Systems (GIS) in finding available parking spaces in urban area at any time of the day, and studying related factors contributing to parking lots occupancy. The study was performed at parking lots and roads of Irbid City-Jordan for the years 2005 and 2006. Parking data were collected for 46 public parking lots. Parking lots data included occupancy as function of time, location with respect to Central Business Discrete (CBD) and shopping centers, area and capacity, roadway classification in front of parking lot, and parking prices. Parking occupancy was correlated to parking price, time of day, CBD and shopping centers locations. Available parking lots and their occupancies were identified using GIS query builder. Results showed that: 1) parking lot price of the first hour, and location with respect to CBD and shopping centers were the most contributing factors that affected the driver decision to choose the most suitable parking lot; and 2) GIS was a viable tool with a great potential for studying parking lots occupancies.

Keywords: *GIS, Parking lots, Parking Occupancy, and Statistical Modeling.*

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1. INTRODUCTION

Due to congested urban area, vehicle owners prefer to park their vehicles in parking lots and walk to their destinations.

In recent years, planners and researchers have focused their attention on parking to solve the current traffic problems, primarily in urban congested area. For the study area, Irbid-Jordan city, where curb parking is common, parking lots are recently used to overcome problem of congestion, help in overcoming high rate of pedestrian accident, and urge pedestrians to change cultural behaviors in using streets rather than sidewalks for walking. Moreover, since the numbers of on-street parking are not sufficient, drivers are willing to park on parking lots for safety purposes.

Convenient and affordable parking lots are welcomed because inadequate, inconvenient or expensive ones will frustrate users. In fact, unaffordable prices of parking lots can make parking problems in other areas. On the other hand, curb parking has been known since long time as a major cause for traffic accidents and congestion in urban cities.

In this paper GIS and analytical modeling were used as tools in order to investigate their potentials to facilitate and manage finding reasonable price and available parking lots spaces, near to CBD and shopping centers at any condition and any time of the day, aiming to reduce pedestrian accidents.

2. LITERATURE REVIEW

Safety improvement task in urban areas could be done through development of criteria to identify pedestrian high accident locations and proper parking locations distributed over metropolitan area (Cui 2000). These locations would help planners and decision makers to setout pedestrian safety programs and give a better understanding of the causes of pedestrian accidents (Latinopoulou *et al.* 2001)). GIS could help a lot in this domain because it has spatial analysis capabilities. However, data could be collected from municipalities, police departments, and any other sources.

Moreover, bus stop usage was associated with pedestrian accidents along different parking facilities (Jordan Traffic Institute 2002).

Literature also showed that pedestrians, including pedestrians not owning vehicles and pedestrians parked their vehicles at parking facilities, were subjected to vehicle-pedestrian collision (Schneider *et al.* 2001). Therefore, it was important to search for vacant parking space in spatially homogeneous metropolitan areas located near to the pedestrian's destination in order to minimize walking distance. This means that vacant parking spaces located near pedestrian's destination potentially would decrease vehicle-pedestrian accidents (Small *et al.* 1995). In their study, they presented a simple model of parking congestion that focused on drivers search for vacant parking space in spatially homogenous metropolitan area. They found that parking pricing was a potentially a powerful tool to regulate traffic congestion in order to avoid vehicle-pedestrian collision. However, typical questions for parking are still to be answered using GIS. These questions may include: Show parking lots that are within a selected distance from a public building or shopping center? Show the best or optimal route from a public building or a mid-block street point to a destination parking lot?

Obviously, literature shows scattered and out of focus usage of GIS in the domain of parking lots.

3. DATA COLLECTION

Data were collected for 46 public parking lots in Irbid-city, Jordan using an hourly-based field survey for the years 2005-2006. The data were collected for 12 hours of two days at the beginning and the middle of each week. The following variables were included in the parking lots study:

1. Occupancy of each parking lot for twelve hours period (8 am-8 pm).
2. Location of parking lot with respect to CBD (inside, near or far).
3. Location of parking lot with respect to shopping area (inside, near or far).
4. Area of Parking lots (m^2).
5. Classification of roadway in front of the parking lot (arterial, collector or local).
6. Parking price in Jordanian Dinner (JD) according to time (1^{st} hour, 2^{nd} hour and 3^{rd} hour).

4. GIS LAYERS

The following GIS layers were developed in order to identify entities, attributes, and relationships of variables:

1. Parking lots locations and their attributes (Figure 1). The following attributes were used for this layer:
    - *Shape*: The type of shape of the specific lot (Polygon)
    - *Lot_Name*: The unique name of the lot.
    - *Lot_Id:* The unique identification number of the lot.
    - *Capacity:* The number of parking spaces at every parking lot.
    - *Area:* The area of each parking lot (m^2)
    - *Type_ of road:* Roadway classification (arterial, collector or local).
    - *Ava_8-20:* Number of available parking spaces.
    - *CBD:* Distance to or from CBD (inside, near or far)
    - *Shopping:* Distance to or from shopping area (inside, near or far).
    - *Price 1-3:* Price of parking for the (1^{st}, 2^{nd} and 3^{rd} hour).

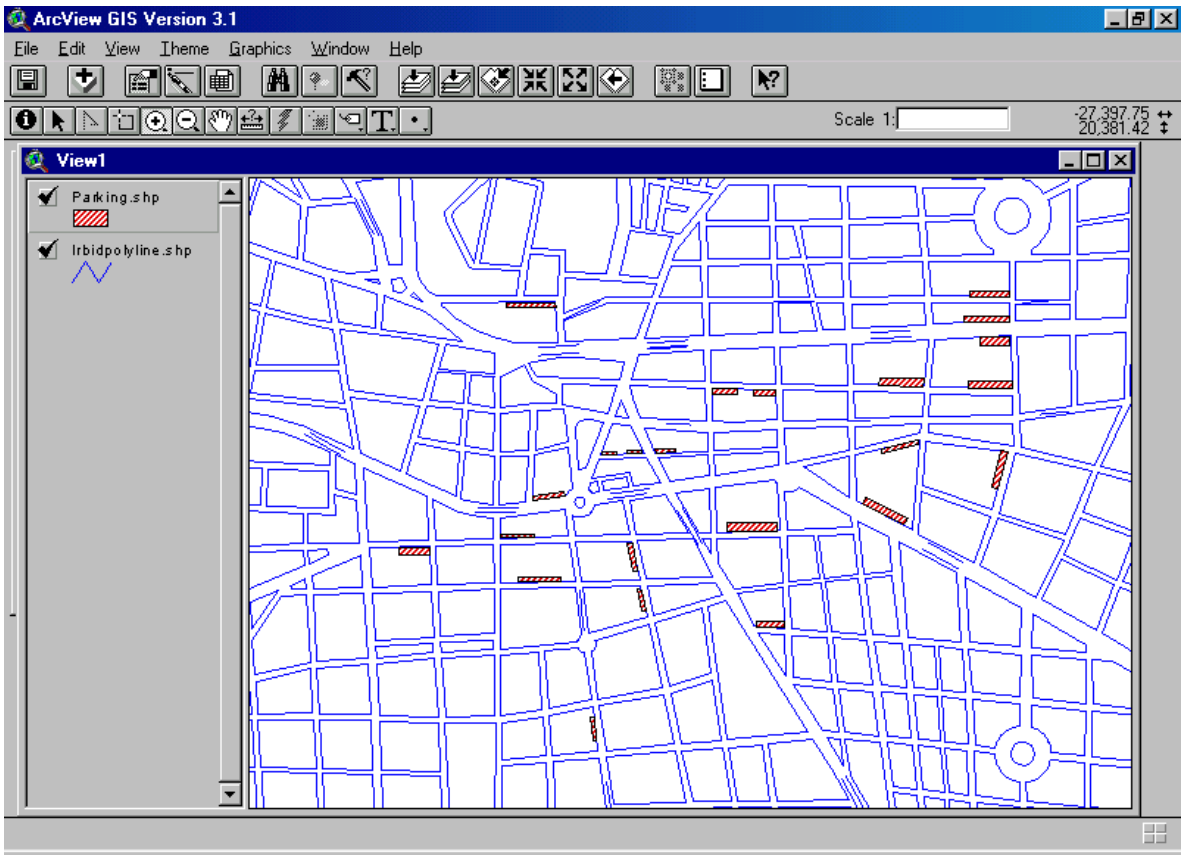

Figure 1: Parking Lots Locations at the CBD Area.

Tables 1 and 2 respectively show the collected database and the available parking spaces as function of time for selected number of parking lots.

Table 1: Database of Selected Parking Lots.

Parking Lot Name (Lot_Name)	Parking Lot Capacity	Area (m-square)	Type_ of_ Road	Location with Respect To CBD	Location with Respect To Shopping Centers	Price_1 Jordanian Dinner (JD)	Price_2 (JD)	Price_3 (JD)
Al.hashme	16	400	Arterial	inside	inside	0.250	0.15	0.10
Al.matlag	50	882	Arterial	inside	inside	0.300	0.20	0.10
Al.smadi	56	750	Collector	Near	Near	0.300	0.15	0.10
Al.aman	100	1500	Collector	Near	Near	0.250	0.15	0.10
Al.gosayre	56	1600	Collector	inside	inside	0.300	0.15	0.10
A.gawazat	50	840	Collector	inside	inside	0.250	0.15	0.10
Al.shamayla	120	2500	Arterial	inside	inside	0.250	0.05	0.05
Palastine	40	800	Arterial	inside	Near	0.250	0.10	0.10
Al.baladeya	88	2300	Collector	Near	inside	0.000	0.15	0.10
Waled Khares	30	220	Collector	Near	inside	0.300	0.15	0.10
Hgaze	50	1000	Collector	inside	Near	0.300	0.10	0.10
Alsharg	50	620	Collector	inside	inside	0.300	0.15	0.10
Khrese	14	400	Collector	Near	inside	0.300	0.15	0.10
Alaa	15	300	Collector	Near	Near	0.200	0.10	0.05
Aaros Alshamal	30	700	Collector	Near	Near	0.250	0.10	0.10
Alahwa	50	2000	Collector	Near	inside	0.250	0.15	0.10
Sarkesyan	100	1500	Local	inside	inside	0.250	0.05	0.05
Khalel	16	250	Local	inside	inside	0.300	0.10	0.10
Goreya	20	300	Local	inside	inside	0.300	0.15	0.10
Khalel Alsakran	35	800	Arterial	Far	inside	0.300	0.25	0.15
Abu Obead	12	300	Local	inside	inside	0.300	0.15	0.10
Alrahba	30	750	Collector	Near	Near	0.300	0.15	0.10
Alsbeahe	57	1050	Collector	Near	Near	0.300	0.15	0.10
AL.hamed	50	1300	Collector	Far	inside	0.300	0.25	0.15

Table 2: Available Parking Spaces of Selected Parking Lots as function of Time.

Parking Lot Name (Lot_Name)	Ava_8	Ava_9	Ava_10	Ava_11	Ava_12	Ava_13	Ava_14	Ava_15	Ava_16	Ava_17	Ava_18	Ava_19	Ava_20
Al.hashme	6	1	0	0	0	0	0	2	1	6	8	13	14
Al.matlag	25	10	5	0	0	3	15	25	30	35	38	42	50
Al.smadi	25	10	9	5	3	0	0	6	20	29	30	31	33
Al.aman	50	39	20	0	0	20	34	66	67	90	95	100	100
Al.gosayre	31	16	11	6	3	0	11	31	36	38	46	53	56
A.gawazat	27	9	4	1	0	0	8	27	38	47	48	50	50
Al.shamayla	65	30	26	19	9	2	20	47	58	100	115	119	120
Palastine	29	22	14	10	8	1	4	13	25	32	35	39	40
Al.baladeya	48	29	11	6	1	22	28	65	77	85	87	88	0
Waled Khares	27	21	15	11	7	2	1	8	19	24	27	30	30
Hgaze	48	40	31	20	8	2	0	9	28	40	45	48	50
Alsharg	40	25	17	10	5	3	5	27	35	43	48	49	50
Khrese	12	7	0	0	0	0	2	4	7	9	12	13	14
Alaa	0	0	0	0	0	0	0	1	6	11	13	14	15
Aaros Alshamal	5	1	0	0	0	3	17	30	30	38	45	48	50
Ala7wa	5	0	0	0	0	0	0	0	0	0	0	0	0
Sarkesyan	44	39	18	8	12	10	20	45	79	89	97	98	100
Khalel	12	4	1	0	0	0	2	1	7	8	11	14	16
Goreya	16	8	5	4	4	3	6	5	11	12	15	18	0
Khalel Alsakran	27	21	11	4	3	5	0	6	7	17	25	31	34
Abu Obead	10	5	2	1	0	0	0	1	5	7	10	11	12
Alrahba	28	25	15	11	7	2	3	11	19	24	27	30	30
Alsbeahe	15	16	12	7	6	0	0	0	0	4	18	20	30
AL.hamed	45	40	26	10	5	3	0	18	35	40	35	42	49

5. ANALYTICAL MODELING

Step-wise regression analysis was used to find the relationship between dependent (predictor) variable and its associated independent (criterion) variables. SPSS software package was used for this purpose. The best models were selected base on goodness of fit (coefficient of multiple determination – R^2), linearity test (F-test), significance of individual variables (t-test), normality of residual distribution and consistency of variance, and standard error of estimate.

In order to predict the parking occupancy (PO), the following independent variables were used: parking capacity (PC), road classification (arterial (A), collector (C), or local (LO)), CBD distance (inside (IN), near (NE), or far (FA)), shopping centers distance (inside (INS), near (NEA), or far (FAR)), area of parking lot (AP), price of first hour parking (P_1), price of second hour parking (P_2), and price of third hour parking (P_3).

For practical purposes, the time interval was divided into three periods 8 a.m. to 12 a.m., 12 a.m. to 4 p.m., and 4 p.m. to 8 p.m.

The best-fit model for the first period (8 a.m. – 12 a.m.) was:

$$PO = 179.42 - 383.01\ (P\_1) \qquad (R^2 = 0.62) \qquad (1)$$

Parking occupancy (PO) for the second interval (12. a.m. to 4 p.m.) was:

$$PO = 76.92 - 12.27\ INS \qquad (R^2 = 0.44) \qquad (2)$$

However, the parking occupancy for the third period was:

$$PO = 13.30 - 0.13\ PC + 6.6\ NE \qquad (R^2 = 0.71) \qquad (3)$$

In the morning time, parking users were concerned about the price of the first hour. This was due to the short period of parking time in the morning that was normally less than an hour. However, in the middle period, parking users normally went for shopping. Therefore, they prefer to park inside shopping centers for convenience purposes and to avoid walking distance. At the evening time and after finishing their work people went to CBD area. Thus, parking capacity and parking near CBD were the two most important factors that affect parking occupancy.

6. FINDING AVAILABLE PARKING LOT

GIS query builder was used to develop a practical procedures in order to select the nearest available parking lots for any selected constraints. The developed methodology depends on GIS query builder capabilities that can locate available parking lots based on:

1. Number of vehicles required to park.
2. Constraints of parking based on:
    a. Time of day.
    b. Location with respect to CBD.
    c. Location with respect to shopping centers and public buildings.
    d. Parking price.
3. Combination of the previous two points.

Arcview software package was utilized for this purpose in order to find the nearest available parking lot (ESRI 1997). Using query option, features and records could be selected. Moreover, information about features, selection of them directly in a view and selection of them according to their attributes, one at a time and in groups is possible. Therefore, parking lots features based on their attributes could be selected using any combination of logical operators (AND, OR, EQUAL etc) between variables.

For example, Figure 2 shows a query building to find the available parking lots for different combinations of used attributes. The equation of query builder used was:

(Ava_10>12) AND (CBD=IN) AND (Price_1<=0.25) (4)

The query equation means to find at least 12 available parking lots at 10 a.m. in the morning inside the CBD area with a price of the first hour less than 0.25 JD. Of course, any combination of variables could be used to find the available parking lots for any specified attributes; i.e. location, time, price, or street type.

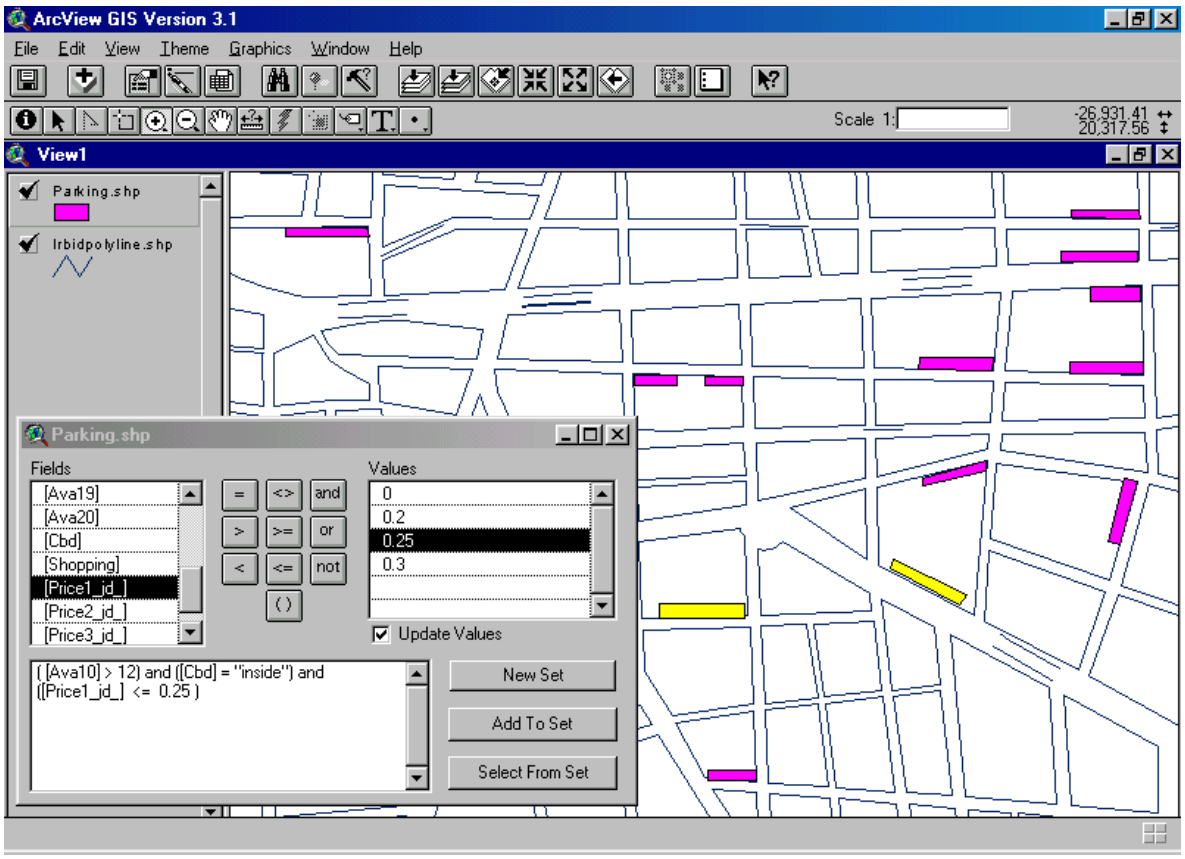

Figure 2: Query Builder to Find Available Parking Lots for Attribute Combinations.

7. DISCUSSION AND ANALYSIS

Defining the spatial maps for parking lots occupancies are very important from the perspective of convenience and traffic jam issues.

The developed GIS-based scheme, for the purpose of finding the nearest available parking lots could give insight to traffic jam issues and pedestrian safety problem in urban areas. The developed maps using this scheme could be updated and useful for planning purposes.

Parking lots occupancies for the period 8 a.m. to 12 a.m. were affected by the price of the first hour parking; however, the rest of the studied variables did not affect it. That was

due to the short parking time normally a person park in the morning time; therefore, the price of the first hour is important. Moreover, at this period there was no traffic congestion because working time in Jordan starts at 8 a.m. and ends at 3 p.m.

On the other hand, parking occupancy for the second period (12 a.m. to 4 p.m.) depended on distance to shopping centers because that time is the shopping time for most of people. People who live in suburban areas and countryside areas prefer to shop before going home. However; the period from 4 p.m. to 8 p.m. was affected by parking capacity and distance to CBD. That was due to traffic congestion at the CBD area at that time.

If query builder procedure is used along with the developed statistical modeling, it is anticipated to have numerous advantages such as:

1. Optimization potential of parking lots usage.
2. Time saving for drivers.
3. Decision making potential for city planners.
4. Knowledge of parking lots occupancy versus time.

8. CONCLUSIONS AND RECOMMENDATIONS

The potential of GIS in analysis of parking lots occupancies was demonstrated. GIS layers were built for different parking lots attributes such as parking lot location, roadway classification, number of available parking spaces, distances to CBD and shopping centers, and parking prices.

It was found that, GIS query could be used as a viable tool to develop a new scheme in order to select nearest available parking lots regardless of the number of constraints and combination for attributes. Spatial digital maps were demonstrated to show available parking lots at any time of the day. The developed GIS-based scheme has the advantages of flexibility, practicality, time saving, safety potential, and ease-of-use guidelines for city planners and decision makers.

Statistical modeling was successfully used to predict parking lots occupancies. It was found that parking occupancy was dependent on the daytime that parking is required. In fact, price of the first hour parking affected the 8 a.m. to 12 a.m. parking occupancy, parking inside shopping centers affected the 12 a.m. to 4 p.m. parking occupancy, and parking lot capacity and parking near CBD constraints affected the 4 p.m. to 8 p.m. parking occupancy.

The findings of this work are anticipated to ease the way for drivers to find the appropriate available parking lot for their vehicles. This may enhance pedestrian safety and reduce travel time during searching for suitable parking lot. Moreover, planners and traffic engineers will be benefited from this study to construct the appropriate pedestrian crossing and parking facilities.

Regardless of the useful findings of this research work that was introduced through GIS technology, many things should be done to enhance parking lots occupancies: evenly

distribute parking lots especially near public buildings, and providing enough parking space are some of the promising recommendations.

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