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Classification tree analysis of factors affecting parking choices in Qatar

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ABSTRACT

Qatar has experienced a significant population growth in the past decade. The growth has been accompanied by an increase in automobile ownership rates leading to parking problems especially in the capital city of Doha. The objective of this study was to find the factors affecting people's choice of parking in this rich developing country when different parking options are available. Two commercial centers located in the city of Doha, Qatar were selected for this study; the City Center mall and the Souq Waqif shopping center. Each location has two different parking options available. Parking options vary in many features including distance to destination, paid/free, covered/open, paved/unpaved, and guarded/unguarded. In addition, the parking options also differed in the ITS infrastructure deployed in the form of intelligent parking space detection system to assist visitors to navigate to an available spot. A survey was handed out to randomly selected visitors at the main entrance of each of these shopping areas to obtain a random sample of study participants. Binary classification tree models were developed to understand the factors associated with binary parking choices at both of these commercial centers. In addition to the demographic factors associated with the parking choice; the reasons for choosing a particular parking option were also explored through the survey. The analysis of survey data presented herein provides an interesting insight into parking choices of the visitors that can be used in planning future parking facilities sand managing existing parking locations. Among the reasons cited by respondents for making their parking choices, "Intelligent Parking Space Detection" was chosen as one of the factors affecting people's choice of parking significantly more often than amenities such as "Wider parking spot". The findings indicate that future parking investments may be better directed towards smart parking solutions.

1. Introduction

Qatar, like most countries with rapidly growing economies, is facing serious parking problems. The number of daily trips in Qatar jumped from 1777,000 trips per day in 2000–5498,000 in 2012. There were 287,500 vehicles on the road in Qatar in 2000, compared to 879,039 in 2012 (Shaaban and Hassan, 2014). The number of cars is increasing, but the parking spaces are not sufficient to accommodate this increase. Due to insufficient parking spaces in the designated lots, the problem of illegal parking is rampant. With the increased number of cars in Qatar, additional parking areas are being added.

In the context of planning for future parking spaces, it is important to understand the factors affecting people' parking location choices. Parking choices in the rapidly growing cities around the world are not well studied. Most past research deals with this issue in the context of the developed countries (Arnott and Rowse, 1999; Hensher and King, 2001; Lambe, 1969). However, with the rapid growth of automobile this is now becoming a critical issue to address in the developing world as well. Towards that end, the objective of this study was to find the factors affecting people's revealed choice of parking when different parking options are available. Two commercial centers in the city of Doha were selected for this study; the City Center mall and the Souq Waqif shopping center. Each of these locations has two different parking options with different characteristics available at each location.

The paper is organized as follows; first details of the two shopping areas are described along with the available parking options. The next section provides details of the survey followed by preliminary analysis and description of the classification tree algorithm. Data mining methods such as classification tree have not yet been used to understand parking choice selection even as they remain popular for several transportation (e.g. Zhou et al.,

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2009) and consumer behavior related applications (e.g. Currim et al., 1988). The most important factors associated with parking selection at the two shopping locations are then identified and analyzed. In addition to the demographic characteristics, the response to the question whether or not a feature of the parking option figured in respondent's selection decision is also explored. Discussion and conclusions from the analysis in the form of lessons for planning and management of parking locations are provided at the end.

There is no question that parking availability may determine a customer's willingness to visit a business, and it is often a sought after feature in urban areas. For years, it has been a standard practice for cities around the world to require developers to provide a minimum number of parking spaces in the new residential and commercial developments. These policies were intended to prevent spillover parking on the street and to respond to the market demand for parking. However, it has become apparent not only that parking problems still exist in many such locations (Waerden et al., 2003) but the problem of traffic congestion may have also been made worse by it (Shoup and Pickrell, 1978). Therefore, instead of mandatory minimums; parking should be planned based on clear understanding of consumer behavior and preferences.

This study attempts to further enhance this understanding by identifying factors associated with parking selection where consumers have a choice between price (at the City Center mall) or proximity and amenities (at Souq Waqif Shopping Center). With multiple parking options available, the choice is made based on the desirability of the options involved. The planning for parking is complicated by the fact that the desirability is also dependent on the demographic characteristics of the consumers. The survey instrument described in the next section is designed with this issue in mind. As detailed later, the survey is designed to gain not just the reasons for choosing particular parking, but also identifying what demographic factors affect those choices.

2. Data collection

2.1. Parking areas studied

The first location, the City Center mall, is the largest mall in Doha with five levels, over 370 stores, and a multi-level parking garage with a capacity of 2000 parking spaces (see P2 in Fig. 1). The City Center mall welcomes an average of 45,000 visitors daily and up to 70,000 visitors on peak days like public holidays. The parking garage P2 is close to the destination (inside the mall building), paid, guarded, covered, and paved. This parking garage is also equipped with intelligent parking space detection system to assist the visitors to navigate to available parking spaces. On the other hand, many people use a nearby vacant land to park their vehicles for free (see P1 in Fig. 1). P1 is far from the destination, unguarded, unpaved, open, and of course without any Intelligent Transportation Systems (ITS) support for the drivers. The users, parking at this location, are required to walk approximately 250 meters on the existing sidewalk and cross a signalized intersection to reach the City Center mall. It should be noted that the temperature reaches 50 degrees Celsius (122 degrees Fahrenheit) during the summer in Doha. The capacity of P1 was difficult to determine since the area is not marked or paved.

The second location, Souq Waqif, is an important shopping center in Doha. Literally translated to “the standing market," this shopping destination is the most crowded spot in the city. It is home to dozens of restaurants, hotels, and shopping areas as well as a host to several art galleries and events. It is considered one of the top tourist destinations and the main heritage landmark of Doha. There are two main parking areas serving Souq Waqif, one at ground level adjacent to Souq Waqif (see P4 in Fig. 1). The capacity of this parking area is 600 cars. This parking is close to the destination, paid, guarded, and paved. Another new underground car park with an underground air-conditioned walkway connecting to Souq Waqif became available in 2012 (see P3 in Fig. 1). P3 consists of three underground basement floors that can accommodate up to 1500 vehicles. This parking option is somewhat far from destination but is paid, guarded, and paved. This parking garage, P3, is equipped with intelligent parking space detectors, which are installed in each parking space, to show a green light for unoccupied spaces. It should be noted that the parking fees at the two locations are the same. Users parking at P3 are required to walk approximately 300 meters in an air-conditioned underground walkway to reach the Souq Waqif shopping center.

2.2. Methods

In this study, a questionnaire was carried out at the two major commercial spaces in order to identify the factors associated with parking selection when consumers have a choice between price, proximity, and amenities. To obtain a representative sample of the population who visits the two locations, it was decided to use the face-to-face interview method. Mail-in questionnaires, phone interviews, and internet-based surveys were not considered since it would be difficult to collect the information about the parking usage.

The questionnaire included questions regarding gender, age, nationality, and income. These demographic questions were an important aspect of this questionnaire and were designed to

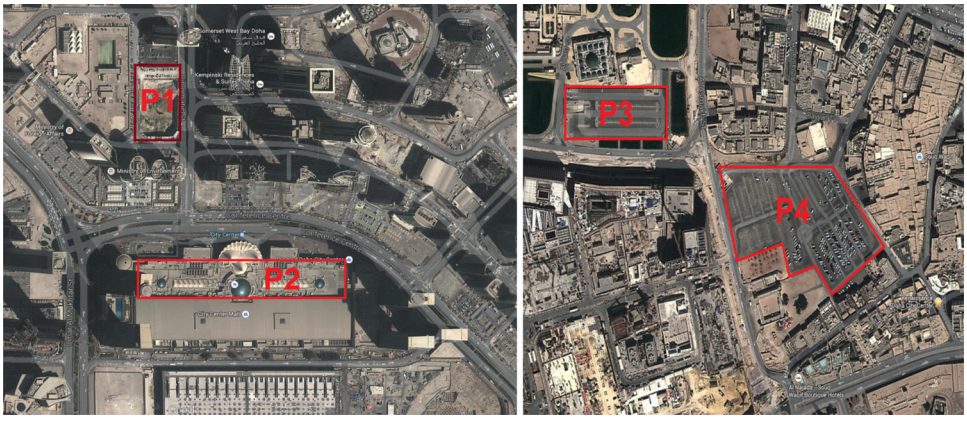

Fig. 1. (a) City Center Mall Parking options, (b) Souq Waqif parking options.

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determine whether these factors influence a participant's answers, opinions, and suggestions. This information also enabled cross-tabulation and comparison of subgroups to see how responses vary between them. The visit frequency and stay time were also collected to assess the factors influencing parking preferences. The last set of questions in the survey was related to the reasons for choosing a specific parking location. Participants answered these questions by choosing "all that applies" from a set of given options. Participants were also allowed to enter other options if appropriate. These verbatim were read, categorized, and coded for analysis by implementing standardization in the data entry process.

2.3. Sampling

The minimum sample size was estimated using the following formula:

$$SS = \frac{Z^2 \times p \times (1-p)}{C^2} \quad (1)$$

where, SS = Sample Size, Z = Z-value, P = Percentage of population, C = Confidence interval (5%). Assuming a 95% confidence level ($z = 1.96$), 5% confidence interval ($c = 0.05$), and $p = 0.05$, the minimum sample size was 384. The research team targeted 500 participants at each location. The survey sample was limited to

Table 1
Respondents characteristics tabulated with parking selection.

Parking			City Center Mall P1	P2	Souq Waqif P3	P4	Grand Total
Gender	Male	Frequency	135	167	171	167	640
		Grand%	16.5%	20.5%	21.0%	20.5%	78.4%
		Column%	84.4%	79.1%	76.3%	75.6%	
	Female	Frequency	25	44	53	54	176
		Grand%	3.1%	5.4%	6.5%	6.6%	21.6%
		Column%	15.6%	20.9%	23.7%	24.4%	
Nationality	Qatari	Frequency	10	75	45	58	188
		Grand%	1.2%	9.2%	5.5%	7.1%	23.0%
		Column%	6.3%	35.5%	20.1%	26.2%	
	Non-Qatari-Arab	Frequency	95	87	109	92	383
		Grand%	11.6%	10.7%	13.4%	11.3%	46.9%
		Column%	59.4%	41.2%	48.7%	41.6%	
	Others	Frequency	55	49	70	71	245
		Grand%	6.7%	6.0%	8.6%	8.7%	30.0%
		Column%	34.4%	23.2%	31.3%	32.1%	
Age	< 25	Frequency	35	71	62	70	238
		Grand%	4.3%	8.7%	7.6%	8.6%	29.2%
		Column%	21.9%	33.6%	27.7%	31.7%	
	26–45	Frequency	92	104	133	105	434
		Grand%	11.3%	12.7%	16.3%	12.9%	53.2%
		Column%	57.5%	49.3%	59.4%	47.5%	
	> 45	Frequency	33	36	29	46	144
		Grand%	4.0%	4.4%	3.6%	5.6%	17.6%
		Column%	20.6%	17.1%	12.9%	20.8%	
Income	Less-than-QR-5000	Frequency	48	49	37	37	171
		Grand%	5.9%	6.0%	4.5%	4.5%	21.0%
		Column%	30.0%	23.2%	16.5%	16.7%	
	QR-5000–10000	Frequency	73	51	126	137	387
		Grand%	8.9%	6.3%	15.4%	16.8%	47.4%
		Column%	45.6%	24.2%	56.3%	62.0%	
	More-than-QR-10000	Frequency	39	111	61	47	258
		Grand%	4.8%	13.6%	7.5%	5.8%	31.6%
		Column%	24.4%	52.6%	27.2%	21.3%	
Visit frequency	1-per-week	Frequency	80	116	111	123	430
		Grand%	9.8%	14.2%	13.6%	15.1%	52.7%
		Column%	50.0%	55.0%	49.6%	55.7%	
	1–3-per-week	Frequency	54	61	87	85	287
		Grand%	6.6%	7.5%	10.7%	10.4%	35.2%
		Column%	33.8%	28.9%	38.8%	38.5%	
	>3-per-week	Frequency	26	34	26	13	99
		Grand%	3.2%	4.2%	3.2%	1.6%	12.1%
		Column%	16.3%	16.1%	11.6%	5.9%	
Stay time	< 1-hour	Frequency	17	45	48	44	154
		Grand%	2.1%	5.5%	5.9%	5.4%	18.9%
		Column%	10.6%	21.3%	21.4%	19.9%	
	1–3-hour	Frequency	110	109	140	128	487
		Grand%	13.5%	13.4%	17.2%	15.7%	59.7%
		Column%	68.8%	51.7%	62.5%	57.9%	
	> 3-hour	Frequency	33	57	36	49	175
		Grand%	4.0%	7.0%	4.4%	6.0%	21.4%
		Column%	20.6%	27.0%	16.1%	22.2%	
Grand total	160	211	224	221	816		
	19.6%	25.9%	27.5%	27.1%	100.0%		

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Table 2
Contingency tables for parking choices at the City Center Mall and the categorical demographic variables.

Parking by gender				
Parking	Gender			
	Female	Male		Overall data
0; Lot P1 in Fig. 1	36.23	44.7		43.13
1; Lot P2 in Fig. 1	63.77	55.3		56.87
Overall Data	69	302		371
Parking by age				
Parking	Age			
	<25	26–45	>45	Overall data
0; Lot P1 in Fig. 1	33.02	46.94	47.83	43.13
1; Lot P2 in Fig. 1	66.98	53.06	52.17	56.87
Overall Data	106	196	69	371
Parking by nationality				
Parking	Nationality			
	Qatari	Non-Qatari-Arab	Other	Overall data
0; Lot P1 in Fig. 1	11.76	52.2	52.88	43.13
1; Lot P2 in Fig. 1	88.24	47.8	47.12	56.87
Overall Data	85	182	104	371
Parking by income				
Parking	Income			
	Less-than-QR-5000	QR-5000–10000	More-than-QR-10000	Overall data
0; Lot P1 in Fig. 1	49.48	58.87	26	43.13
1; Lot P2 in Fig. 1	50.52	41.13	74	56.87
Overall data	97	124	150	371
Parking by stay time				
Parking	Stay time			
	<1-hour	1–3-hour	>3-hour	Overall data
0; Lot P1 in Fig. 1	27.42	50.23	36.67	43.13
1; Lot P2 in Fig. 1	72.58	49.77	63.33	56.87
Overall Data	62	219	90	371
Parking by visit frequency				
Parking	Visit frequency			
	1-per-week	1–3-per-week	>3-per-week	Overall data
0; Lot P1 in Fig. 1	40.82	46.96	43.33	43.13
1; Lot P2 in Fig. 1	59.18	53.04	56.67	56.87
Overall Data	196	115	60	371

drivers who entered the two selected commercial centers after parking their cars. The survey was not limited to any special group of the population and was directed to all people of both genders with different ages and nationalities. It is worth noting that Qatar in general and Doha, in particular, have a large number of expatriates from all over the world living there. The questionnaires were handed out randomly at the entrance locations of these commercial centers after asking the participants if they arrived in a personal vehicle. The team members explained the questionnaire to the participants in person and then collected back the filled in questionnaire. All 500 distributed survey forms in Souq Waqif were collected, however; only 445 surveys forms were considered complete and used in the analysis. Out of 500 distributed survey forms in the City Center mall, only 371 survey forms were considered complete and used in the analysis. The remaining forms were either not returned or had more than 30% missing responses, and, therefore, were disregarded.

3. Data details

The majority of the participants were male (78.4%). It is in line with the adult population of Qatar (75.3% male in June 2014, Ministry of Development Planning and Statistics, 2014). Middle-aged participants, aged 26 years to 45 years, turned up to be more than half of the sample size with (53.2%). The nationality of the drivers was included in the survey form due to the cultural diversity of the country. The participant drivers included Qatari nationals (23%), non-Qatari Arab (23.04%), Asians (16.79%), and others including the Europeans and United States nationals (13.24%). As far as income, 21.7% of the participants had low income (less than QR 5000 per month), 47.4% of the participants were part of the middle-income group (between QR 5000 and 10,000 per month) and 31.6% of the participants had high income (more than QR 10,000 per month). Detailed information about participant demographics and their responses is provided in Table 1.

3.1. Analysis of the Factors Affecting Parking Choice

This study employs the classification tree model to explain the demographic characteristics associated with parking choices made by the customers. Two binary classification tree models were developed, one for each commercial center with the parking option being the target variable. The advantage of the classification tree over parametric models (e.g., logit model employed by Hunt and Teply, 1993) is that these models do not rely on underlying assumptions about the data distribution. Classification trees have been used extensively for understanding and predicting consumer behavior (e.g., Lemmens and Croux, 2006; Currim et al., 1988) though not, to our knowledge, in understanding parking behavior.

3.2. Classification Algorithm

A classification tree for binary classification problem represents the segmentation of the data set being analyzed, created by applying a series of if-then rules. Each rule assigns an observation to a group based on the value of one or more input variables. One rule is applied after another, resulting in a hierarchy of groups within groups. The hierarchy is called a tree, and each group is called a node. The final or terminal nodes are called leaves. The advantage of the classification tree over other data mining tools, such as neural networks, is that it produces a model that is represented by interpretable logic statements. These logic statements are very helpful in understanding the effect of independent variables on binary target variable and have been used in several transportation applications such as traffic safety (e.g., Pande and Abdel-Aty, 2006) and pavement management (e.g., Zhou et al., 2009).

The basic idea of building a classification tree model involves splitting each (non-terminal) node such that the descendent nodes are 'purer' than the parent node. To achieve this, a set of candidate split rules is created, which consists of all possible splits for all variables included in the analysis. For example, for a dataset with 200 observations and six input variables there would be $200 \times 6 = 1200$ splits available at the root node. These splits are then evaluated based on a Gini reduction criterion to choose amongst various available splits at every non-terminal node (including the root node). The use of Gini index, essentially a measure of variability in categorical data, as the split criteria were proposed by Breiman, 1984 in his classic work on Classification and Regression Trees. The classification tree algorithm was implemented using R (R Development Core Team, 2013). Gini reduction criterion was applied recursively to the descendants, which become the parents to successive splits, and so on. The splitting

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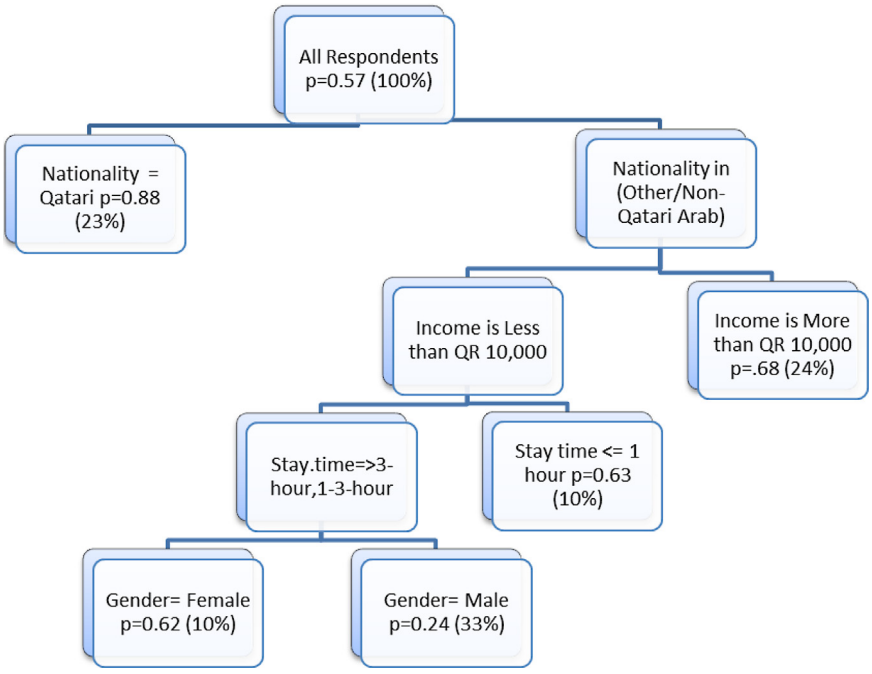

Fig. 2. City Center Mall parking choice classification tree.

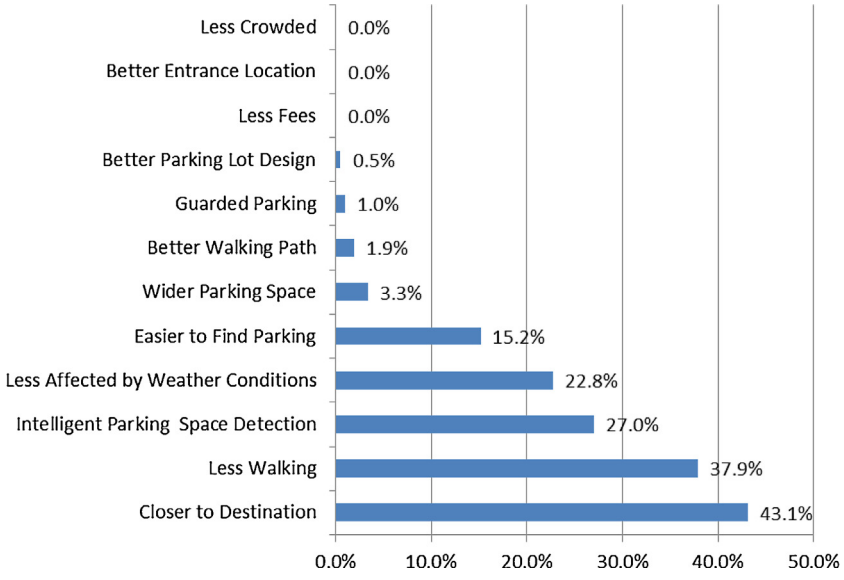

Fig. 3. Reason(s) cited for choosing paid parking lot.

process is continued until the criteria of minimum reduction in Gini index and/or minimum size of a node are satisfied.

4. Parking selection at the City Center mall

Six characteristics for the City Center mall visitors (tabulated in Table 1) were used for binary classification analysis. The target variable for this analysis was the choice made by the survey respondents between Parking Lot P1 (Binary target value = 0) and P2 (Binary target value = 1). A cross-tabulation of the six categorical variables and parking choice is provided in Table 2. As shown in Table 2, it appears that female, higher income (more than QR 10,000 per month), Qatari citizens, and respondents less than 25 years of age are more likely to use the paid parking. However, how these variables interact is not clear from Table 2.

The classification rules from the tree algorithm can, in fact, better explain their interactions.. The classification tree resulting from these variables is provided in Fig. 2. Each terminal node (or leaf) of the tree shown in the figure depicts the probability (p) of the respondent in that node choosing parking lot P2 (i.e., the closer paid parking lot). It also shows the percentage of observations contained within that leaf in parenthesis. This information is also provided for the initial node which represents the complete validation dataset. Note that classification tree models were estimated with 80% (randomly drawn) data used for training and the remaining 20% of the dataset used for validation. It may be observed that 57% of the respondents in the validation dataset chose Parking lot P2.

It may be observed in Fig. 2 that a Qatari citizen visiting the City Center mall is much more likely to use the closer paid parking lot

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Table 3
Contingency tables for parking choices at Souq Waqif and the demographic variables.

Parking by gender

Parking	Gender		
	Female	Male	Overall data
0; Lot P3 in Fig. 1	49.53	50.59	50.34
1; Lot P4 in Fig. 1	50.47	49.41	49.66
Overall Data	107	338	445

Parking by Age

Parking	Age			
	< 25	26–45	> 45	Overall data
0; Lot P3 in Fig. 1	46.97	55.88	38.67	50.34
1; Lot P4 in Fig. 1	53.03	44.12	61.33	49.66
Overall Data	132	238	75	445

Parking by nationality

Parking	Nationality			
	Qatari	Non-Qatari-Arab	Other	Overall Data
0; Lot P3 in Fig. 1	43.69	54.23	49.65	50.34
1; Lot P4 in Fig. 1	56.31	45.77	50.35	49.66
Overall Data	103	201	141	445

Parking by income

Parking	Income			
	Less-than-QR-5000	QR-5000–10000	More-than-QR-10000	Overall data
0; Lot P3 in Fig. 1	50	47.91	56.48	50.34
1; Lot P4 in Fig. 1	50	52.09	43.52	49.66
Overall Data	74	263	108	445

Parking by Stay Time

Parking	Stay time			
	<1-hour	1–3-hour	> 3-hour	Overall data
0; Lot P3 in Fig. 1	52.17	52.24	42.35	50.34
1; Lot P4 in Fig. 1	47.83	47.76	57.65	49.66
Overall data	92	268	85	445

Parking by visit frequency

Parking	Visit frequency			
	1-per-week	1–3-per-week	> 3-per-week	Overall Data
0; Lot P3 in Fig. 1	47.44	50.58	66.67	50.34
1; Lot P4 in Fig. 1	52.56	49.42	33.33	49.66
Overall Data	234	172	39	445

P2 ($p = 0.88$). For non-Qatari citizens, higher income respondents are more likely to use the lot P2 ($p = 0.68$). Similarly, lower and middle-income respondents planning to stay for less than one hour (10% of the respondents) are more likely to use the Lot P2 ($p = 0.63$). Among the lower and middle-income respondents staying longer than 1-hour, the gender of the respondent is likely to be the deciding factor in parking selection. Among them, female respondents had much higher likelihood of selecting the paid parking lot ($p = 0.62$) compared to the male respondents ($p = 0.24$).

The middle and lower income (Income <= QR 10,000) respondents are only likely to choose the Paid parking P2 if their stay time is one hour or less ($p = 0.63$). This particular finding indicates that some short-term parking (for one hour or less), if it can be enforced properly, might be able to attract low to middle-income visitors to use the paid parking P2.

While effects of demographic variables were clear from the classification tree shown above; the reasons why respondents found a particular lot attractive were not addressed by the tree. As mentioned earlier, the survey instrument also asked respondents about reasons for choosing a particular parking. All respondents were asked to select/cite reason(s) for choosing the parking area that they, in fact, chose. For respondents who chose the paid parking the percentage of respondents citing different reasons are shown in Fig. 3. Respondents were asked to cite more than one reason, if applicable. Hence, the percentages shown in Fig. 3 don't add up to 100.

As expected, proximity to the actual shopping area, less walking, and protection from the elements are key reasons cited by respondents choosing the paid parking. It is interesting to note that better parking lot design, guarded parking, better walking path, were cited by less than 2% of the respondents. Wider parking space was also cited by only 3.3% of the respondents for choosing the paid parking. The only parking 'conveniences', other than proximity, that were cited as reasons by a sizable proportion of respondents were "Intelligent Parking Space Detection" and "Easier to find parking". The lesson for planners in rapidly developing city centers from this finding would seem to be that parking investments might be better directed at ITS equipment compared to the creation of wider parking spaces.

5. Parking selection at Souq Waqif

Next step in the analysis was to repeat the same steps for the Souq Waqif shopping area. The frequency distribution of six demographic characteristics for the Souq mall visitors vis-à-vis the binary target variable is shown in Table 3. Note that the binary target variable, in this case, was the choice between Parking lot P3 (target = 0) and Parking lot P4 (target variable = 1; also see Fig. 1). It should be noted that both lots have the same pricing but the lot P4 is closer to the shopping area. On the other hand, the lot P3 has more than 10 times the parking capacity, a vehicle detection system to guide users to empty spots, and wider parking spaces that can easily accommodate SUVs (larger size Sport Utility Vehicles).

The distribution of the two parking choices is very close to 50–50 in Souq Waqif data. Based on the contingency tables respondents over 45 years of age, Qatari citizens and those who come in for more than 3 h are more likely to choose the closer Parking option P4.

The classification tree resulting from these variables is provided in Fig. 4. Each terminal node (or leaf) of the tree shown in the figure depicts the probability (p) of respondent choosing parking P4 (parking adjacent to the Souq Waqif) along with the percentage of observations contained within that leaf. This information is also provided for the initial node which represents the complete validation dataset. Note that validation dataset was 20% of the dataset collected for Souq Waqif.

Respondents with more than three hours stay time are more likely to park in the lot P4 ($p = 0.60$). Among the respondents staying for a shorter duration (less than one hour or between 1 and 3 h), older respondents (Age over 45) are more likely to use the adjacent Parking P4 ($p = 0.55$). For younger respondents, who are Qatari citizens, visit frequency is the critical factor. Those who visit the center once per week or less; are less likely to use the lot P4 ($p = 0.41$). On the other hand, more frequent Qatari citizen visitors are the likeliest cohort to be using the lot P4 ($p = 0.72$).

Income level is not a significant factor in this classification tree likely because the pricing is exactly the same for the two lots. In terms of desirability, the two options available at Souq Waqif are harder to differentiate (e.g., both are paid lots, and the split was close to 50-50 among the respondents).

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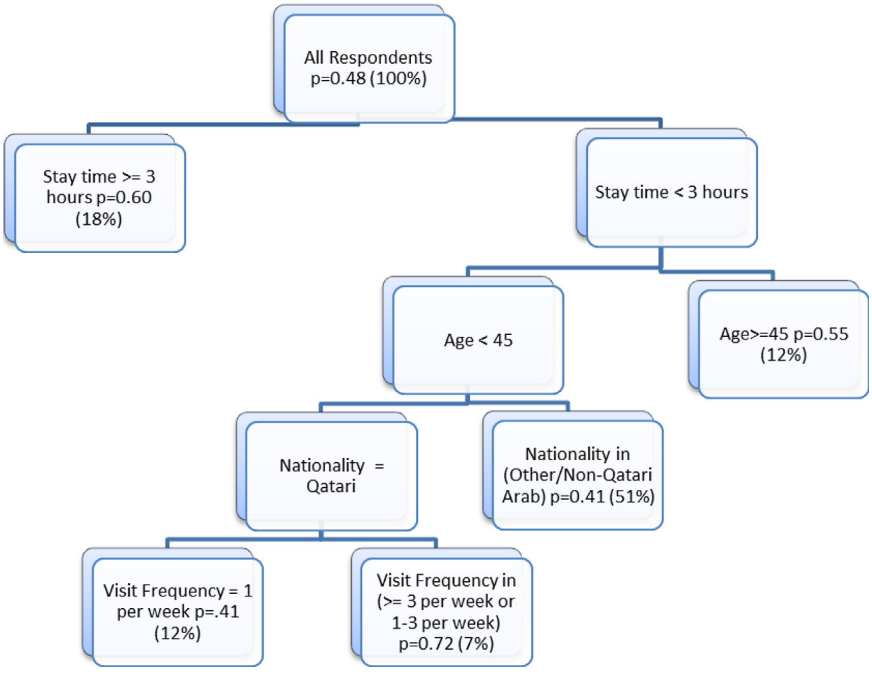

Fig. 4. Souq Waqif parking choice classification tree.

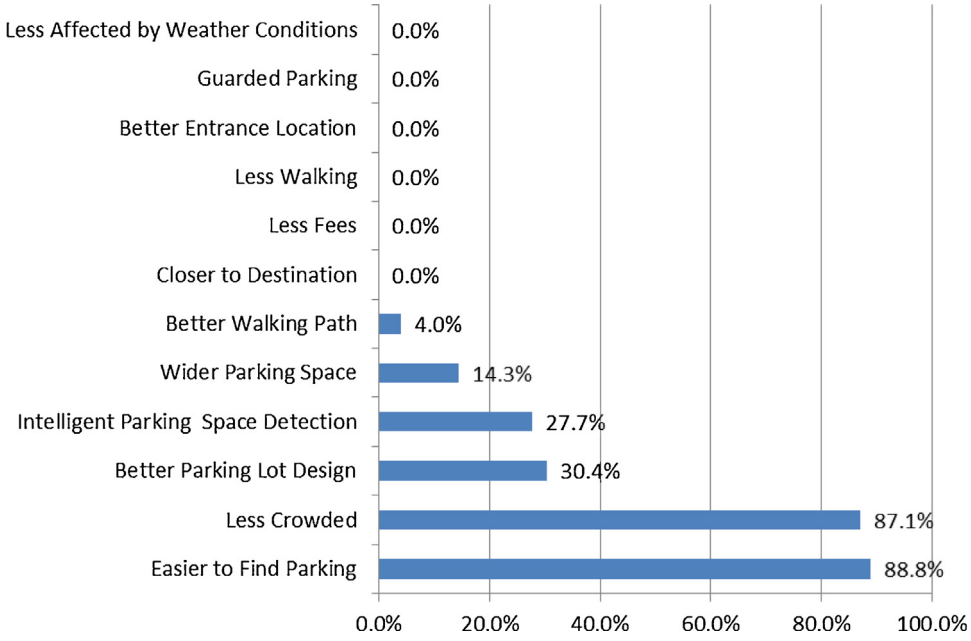

Fig. 5. Reason cited for choosing farther parking lot.

The classification performance of the tree shown in Fig. 3 (for Souq Waqif) had worse classification performance than the tree shown in Fig. 2 (for City Center). It may also be observed that the leaves (terminal nodes) for the City mall classification tree (Fig. 2) were 'purer' in the sense that more of them had a higher percentage of one target variable class or the other compared to Souq Waqif classification tree (Fig. 4). Even though we note the relative classification performance of the two models; we are not delving into the details of prediction accuracy of the two models. The reason being that the goal of this study is to understand the factors associated with respondents' decision and not necessarily to 'predict' their choice.

The next step in the analysis was to examine the reason revealed by the respondents for choosing the farther parking lot, P3, even when the price is the same. Easier to find parking and less crowded were cited by almost 9 out of 10 respondents as a reason for choosing the farther parking lot. These two factors are related with the capacity difference between the two parking options. In addition, "Intelligent Parking Space Detection" was also cited by 27.7% of the respondents. It is also noteworthy that about half the respondents cite wider parking spaces (14.3%) compared to the ITS-based parking spot guidance. This finding is consistent with the reasons cited by the City Center mall visitors in the preceding section where "Intelligent Parking Space Detection" was also cited

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by significantly higher percentage of respondents compared to wider parking spaces as shown in Fig. 5.

6. Conclusions

Parking choices in the rapidly growing cities around the world are not well studied. This study tries to address this gap by analyzing parking choices made by visitors at two commercial centers in the city of Doha, Qatar. One of the commercial centers was the City Center mall, where the choice was between free and paid parking. The other was the Souq Waqif shopping center where the choice was between two paid parking options with one being low capacity/close proximity and the other being farther with significantly higher capacity.

The study applies the classification tree model to understand factors associated with these choices. The first application of this data mining technique led to some interesting findings with regards to the parking choice selection. At the city center mall, as expected, respondent income was an important factor in parking selection with higher income respondents being more likely to select the paid parking. However, even the lower income respondents were likely to use the paid parking if they were visiting the mall for less than one hour. It points to the need for having some spots reserved for short-term (possibly up to 60 or 90 min) parking that makes it easier for lower income visitors to be able to park at the more convenient location.

At Souq Waqif, both parking options had the same pricing structure. Hence, income was not a significant factor in parking choice. Interestingly, Qatari locals of age less than 45 years, who visited the shopping center more than once a week were the likeliest cohort to use the adjacent lot (P4) with lower capacity. Some members of this cohort may be lured away from the capacity constrained lot, P4, if pricing structure at P3 offers discounts to frequent Souq Waqif visitors.

Among the reasons cited by respondents for making their parking choices it appeared that wider parking spaces ranked much lower than “Intelligent Parking Space Detection”. It is interesting in light of the high proportion of SUVs that are part of the vehicle fleet in contemporary Qatar. The finding indicates that, in spite of the popularity of the SUVs, future parking investments may be better directed towards smart ITS based solutions.

The survey and the analysis of survey data presented herein provide some interesting insight into parking choices in Qatar. In the future, it would be interesting to contrast them with findings from other cities around the Middle East and the rest of the world.

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