International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

Enhancement of Parking Management System in Cairo using Smartphones

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Abstract*—Over the past two decades, traffic authorities in many cities have developed so-called parking guidance and information systems (PGI) to help drivers to find the available parking spaces. In Cairo, the capital of Egypt, the PGI has been recently implemented in 2015. This research mainly aims to develop and assess a new approach for introducing parking information based on a smartphone application that can inform the users about the number of available parking spaces within the studied garages not only in the real- time but also in the near future based on historical data. The need for such an application was investigated before deployment by a questionnaire survey, while post-deployment feedback was used to evaluate the developed application as a tool to enhance and overcome the current parking management system defects. In addition, the current parking management system has been evaluated based on drivers' opinion. The results showed that despite the PGI system has been deployed since 2015, only 70% of the participants were aware of this system. Out of them, 23% used the system. The main purpose of this is that the VMSs were not working sufficiently and some of them are not clear enough to the drivers. Around 46% of the interviewed drivers stated that when they didn't find a space in the garage, they usually do not find an alternative parking space easily and they waste around 15 to 20 minutes searching for available parking spaces, while the average search time for those who are using the system was between 5 to 10 minutes. Finally, 99% of the participants believe that using more advanced parking guidance system through smartphone application will be more useful. A smartphone application has been developed as an advanced alternative tool for providing users with the number of available parking spaces not only in the current time but also in the near future time. This was done by developing predictive models for parking spaces availability at each garage over the daytime using the collected data. This application was evaluated based on the feedback of about 70 participants who used the application. The feedback analysis showed that 82% of the users were satisfied with the application, only one out of 70 participants have complained about the ease of use. Also, 89% of the participants have agreed that the application help in reducing parking search time with an overall average of 8 minutes.

***Index Terms*— ITS, PGI systems, PGI systems evaluation, smart parking, smartphones applications.**

Revised Manuscript Received on October 30, 2019.

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I. INTRODUCTION

Parking availability is considered an important factor affecting both private car-based trip decisions and traffic conditions in urban areas. Finding a parking space, especially at city centers, is not an easy task for the majority of drivers. The acts of cruising for parking can arise from different situations: desirable parking near a destination being at capacity, price differences among available parking facilities, or simply a driver's lack of familiarity with their surroundings. Vehicles searching for vacant parking spaces negatively impact traffic conditions and the environment [1]. On a daily basis in some cities, it was estimated that 30% of traffic congestion in an urban downtown area is caused by vehicles in search for available parking space, and it takes the driver anywhere between 3.5 to 14 minutes in a typical search [2]. In this situation, providing information regarding the available parking spaces is very useful to the drivers. Accordingly, PGI systems are widely implemented around the world during the last two decades. This system provides dynamic information about the available parking spaces to the drivers within controlled areas.

In June 2015, the ministry of state for environmental affairs in cooperation with Cairo Governorate implemented PGI system in Cairo. The system provides the real-time available number of parking spaces for ten garages located at the city center; this information is disseminated using 14 VMS located at main routes leading to the city center. Despite this system has been activated four years ago, the effectiveness of this system and the driver's perception and evaluation have not been yet investigated. Therefore, a question that to what extent the system solved the problem of searching an available parking space has been raised. Accordingly, the objective of this research is to evaluate the current parking management system based on drivers' opinion, and to develop and assess an Android application to be used on a handheld device running on the Android operating system. The proposed smartphone application which is called "parking information" can be used to provide users with the estimated number of available parking spaces in the studied garages in the real-time. Also, it can be used to provide users with the estimated number of available parking spaces at the time the user will arrive at the garage or at any time that user specify whether in the same day or any other day based on the collected data

II. METHODOLOGY OF RESEARCH

The methodology of this research is as shown in Figure 1. Starting with reviewing the previous researches. The second step was collecting the required data, followed by data analysis. The third step was calibrating and validating models that can simulate the parking availability in each garage in all weekdays which will be used as a database for the developed application. The fourth step was developing an android application and collecting the users' feedback to evaluate the application and to figure out whether it can be used as a tool to enhance and ameliorate the current parking management system.

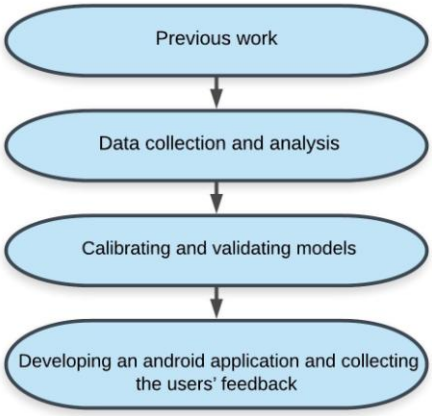


Figure 1: Research methodology

III. LITERATURE REVIEW

A. *History of the PGI system*

Over the past two decades, traffic authorities in many cities have developed so-called parking guidance and information systems. PGIS provide drivers with real-time information about parking spaces availability within controlled areas that guide drivers to the parking lot with available spaces and avoid drivers wandering on roads, decrease queues in front of parking garages, decrease total vehicle-miles traveled, average trip time, energy consumption, and air pollution. [3]. The parking information may be displayed on VMS at major roads, streets, and intersections, or it may be published on the internet, or via cellular phone applications and GIS technologies [4], [5]. The main components of the PGI systems are parking spaces detectors, communication system, and dissemination tools. As stated, before different dissemination tools can be used such as variable message signs (VMS), websites, and cellular phone applications.

PGI Systems are based on the development of autonomous vehicle detection and parking spot monitoring, typically through the use of sensors placed in the vicinity of parking spaces for vehicle detection and surveillance [6]. These sensors can be classified as either "in-roadway" or "over-roadway" [7]. In-roadway sensors are either embedded in the pavement or taped to the surface of the roadway; examples include loop detectors, pneumatic road tubes, etc. Over-roadway sensors are mounted above the surface of the roadway; examples include video, image, etc. [8]. Early developed systems were providing parking availability information on VMS by counting the number of vehicles entering and leaving facilities with inductive loops. Recent systems are providing real-time information about the available parking spots by monitoring the occupied spaces. Many studies have shown that cruising time generally increases with respect to the parking occupancy [9], [10].

B. *PGI evaluation*

A study by Caicedo et al. (2006) showed that drivers who possess the right information have a better chance of getting available spaces comparing than those who don't have parking information [11]. Another study by Patil and Sakore (2014) investigated a smart parking system that has been designed based on a reservation system that allows the users to easily find and reserve a vacant parking space in advance. A comparison has been performed between the performances of four strategies: (a) the first strategy was the blind search, in this strategy when there is no parking information available the drivers keep cruising for parking spaces available and will not stop searching until finding an empty space, (b) The second strategy parking information sharing, where the parking availability information is available for drivers, (C) The third strategy is buffered parking information system, (d) The last strategy is the designed system. The experiment results showed that the driving distance under blind search was the worst, especially during the peak hours; PGI and BPGI are better than blind search when traffic flows increase, and the reservation policy was the best compared with others. It also showed that the average driving distance for the designed system is decreasing at peak time rather than increasing [12].

Another study by Moini et al. (2013) showed through a simulated model of an urban city center, that when real-time occupancy of on-street parking is disseminated to drivers, it results in a reduction of 15% in total travel time [13]. In a survey reported in a study by McDonald and Chatterjee, it is shown that 30% of the 483 surveyed drivers changed their intended parking destination in response to road-side guidance signs indicating space availability at car parks [14]. If this information is accessed before the start of the journey, it can also potentially result in a change of transport mode, for example, a user might decide not to drive if there are no spaces available in the vicinity of his/her intended destination [15].

A smartphone parking application called "ParkPGH" has been assessed in a study by Fabusuyi at al. (2013). The primary objectives of the application were to reduce time in reaching parking spaces, decrease the happenstance of late-coming as a result of difficulties with finding a parking spot, and to improve patrons' perceptions about parking at downtown. The evaluation results of the ParkPGH pilot program indicated that approximately one out of every two respondents reported that the application has reduced the time it takes them to find a parking space. The magnitude of the reduction in search time ranges from one minute to more than 6 minutes with the majority of individuals reporting 4-6 minutes [16].

C. *PGI shortcomings*

Despite that fact that current parking guidance systems increase the probability of finding vacant parking spots, it has several demerits [17].

First, drivers may not actually find vacant parking spots by merely following the guidance. In essence, such systems change driver behavior from searching to competing for parking: more drivers go toward the same available parking spots and it is possible that none is free by the time some drivers arrive, thus forcing re-planning and competition for other spots. Second, even if a driver is successfully guided to a parking spot, such a system encourages increasing the probability of finding any parking spot at the expense of missing the opportunity for a better spot. For example, a driver may pay to park at an off-street parking spot but miss the chance to obtain a nearby free on-street parking spot that may better serve him. Third, from the traffic authority point of view, parking space utilization becomes imbalanced: parking spaces for which information is provided are highly utilized and cause higher traffic congestion in areas where parking spaces are monitored [18].

IV. DATA COLLECTION

To achieve the research objectives, three types of data were required. The first type of data was collected by using a questionnaire survey technique. The questionnaire survey was conducted through physical interviews with a random sample of drivers who used the studied garages. The survey was used to investigate the current situation of parking at the city center, the drivers' evaluation and attitude towards the recently implemented PGI system. Also, the questionnaire survey was used to examine the willingness of the drivers to use a new proposed parking information provision tool based on the advanced technologies of the smartphone applications. The second type of data was the time-varying occupancy of the studied garages, this data was crucial in the calibration and validation of the models that will be used in predicting the number of available parking spaces at studied garages at any time. The last type of data was collected through feedback from the users of the developed application, the feedback was used to evaluate the developed application as a tool to enhance and overcome the current parking management system defects.

A. Case study area

In Cairo, the PGI system has been applied in the city center. The information on the number of available parking spaces for ten parking garages is disseminated using fourteen VMSs. All garages provide a total of 6,300 parking space. Figure 2 shows the locations of the studied garages. Each VMS provides information on the available number of parking spaces for the nearest four garages. The distance between the signs and the garages is varied. **Tahrir** garage is the garage with the highest demand, while **Torgoman** is the garage with the lowest demand. Also, **Tahrir** is the garage with highest-capacity followed by opera, while **Falki** is the garage with the lowest capacity.

Figure 2: Location of the studied garages

B. Questionnaire survey

A questionnaire survey was conducted through direct interviews with a random sample of drivers who used the studied garages. The questionnaire has been formulated to identify the current parking problems, to assess the current parking management system, to determine the average parking search time (time users took to find a garage with available parking spaces), and to investigate the response of the participants towards using a new parking guidance tool based on the smartphone application. The questionnaire form included 19 questions and was divided into four parts. The first part included the demographic information of the participants. The second part provided questions about the ease of parking, the average parking search time and the common problems facing the users. The third part included questions about the current parking guidance system and the extent to which people are aware and satisfied with the service provided. The last part was about the participants' welling for using a new parking guidance system based on smartphone application and to what extent they think this system will be helpful to solve the current problems.

C. Garages' occupancy survey

Data for time-varying occupancy for the studied garages was collected over a whole period of 56 days separated into two different periods 28 days each. The first period was from the 2nd of July 2018 to the 29th of the same month, while the second period was from the 2nd of October 2018 to the 29th of the same month. For the two periods, data was collected frequently for a small time intervals of 15 minutes from 8 A.M to 10:00 PM including both the weekdays and weekends. This data was crucial in the calibration and validation of the models that will be used in predicting the number of available parking spaces at studied garages at any time.

D. Proposed application feedback survey

The last type of data was collected throughout feedback from the application users. This feedback was then used to evaluate the application and to figure out whether it can be used as a tool to enhance and ameliorate the current parking management system to overcome its defects.

V. SURVEY DATA ANALYSIS

A total number of 244 interviews were completed. Most of the participants have age between 18 and 30 years (about 53%) followed by mid-age between 31 and 45 years (about 39%). Regarding the frequency of using the garages, only 4% was using the garages on a daily basis and around 43% was using them occasionally. The major purpose for the trips in the study area was for shopping or other entertainment activities (56%), while only 19% are working trips, while only 19% of the trip purpose is for work. It was found among the shopping and entertainment purposes trips, about 49% of them were using garages occasionally, while 4% of them were often using the garages, and 47% were rarely using the garages. In addition, only 17% of the work trips were using the garages daily, while 74% of them were often using garages, and about 9% of them were using the garages occasionally. It is noticeable that the percentage of drivers who use the garages on a daily basis is significantly small. The purpose for this phenomenon is that those drivers are visiting the city center for working purpose and they prefer to avoid driving in the congested downtown streets. In addition, they argue that it will be really difficult to find an available parking space in the morning peak, especially, if they have a morning delay.

As far as the satisfaction of the users with the garage service, more than 80% of interviewees were not satisfied with the service provided and they complain about the lack of sufficient regulatory signs, limited parking capacities of the garages, and the lack of other facilities such as elevators. Around 46% of the interviewed drivers argued that they usually do not find an available parking space easily, the majority of participants (33%) spent between 10 and 15 minutes in searching for a garage with available parking spaces, while 25% of participants spent between 15 and 30 minutes. The overall average was nearly 16 minutes. The major complaints were recorded from users whose trip purpose were shopping and entertainment. However, working trip users did not complain about the availability of parking spaces. That may be due to their daily experiences and familiarity with the garages or they usually came to the garages at early time where the parking supply is usually bigger than the demand is. In contrast, users with purpose "shopping and entertainment" or "other" are not familiar enough with the garages and their decisions are dependent on the past experience and the VMSs. For instance, if someone of those drivers had a bad experience during the noon while trying to find a parking space, then he will avoid the same area at this time as much as possible. In addition, most of them are not aware of the VMSs locations.

Regarding evaluation of the existing PGI system. Around 70% of users were aware of the system. However, only 21% of them were using it. The main purpose of this is that the VMSs were not working efficiently as they went off many times and some of them can not been seen clearly by the drivers. Also, 79% of the interviewees argued that the locations of the VMSs are not suitable in terms of distance from garages and 84% stated that the number of the VMSs is not sufficient to determine the garage they will head to.

It can be concluded from the data analysis that the PGI is well known by most of the drivers but they do not rely on it. The reasons may be that the VMSs are not working sufficiently as they went off many times and some of them are not clear enough to the drivers, as there may be an obstacle that prevents vision. Despite the fact that PGI system is well known by most of the drivers, the majority of them do not know the locations of the VMS and the number of signs. A comparison between drivers who are using the PGI and those who do not are shown in Table 1. As shown in the table, the PGI is significant in reducing search time as the average parking search time for those who are using the system was nearly 6 minutes, while the average parking search time for those who do not use the system was nearly 18 minutes. Regarding the expected save in parking search time when the proposed application will be available, the average of the expected save in parking search time was about 4 minutes for drivers using the PGI system and about 10 minutes for those who do not use the system. It is noticeable that the major users of the system are drivers who are visiting the City Center at low frequency.

Table 1: A comparison between drivers using PGI and drivers who do not

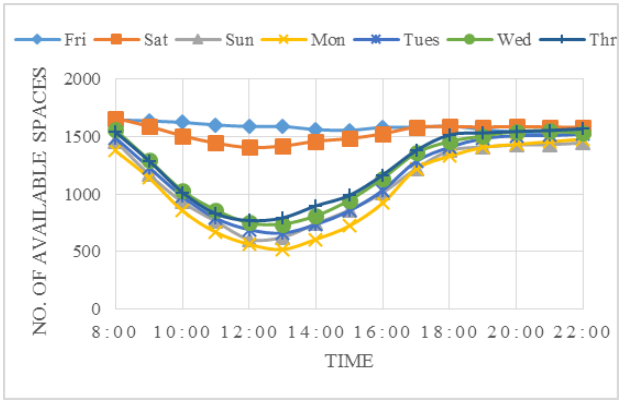
Variables category		drivers using the PGI	drivers do not use the PGI
		percentage	percentage
Trip frequency	Rarely	9.8%	29.5%
	Occasionally	4.9%	38.5%
	Often	1.2%	12.7%
	Daily	0.4%	2.9%
Parking search time	Less than 5 min	7.0%	2.5%
	From 5 to 10 min	7.8%	11.9%
	From 10 to 15 min	1.6%	31.1%
	From 15 to 30 min	0.0%	25.0%
	More than 30 min	0.0%	13.1%
Expected save in the parking search time	Less than 5 min	11.9%	30.7%
	From 5 to 10 min	3.7%	17.6%
	From 10 to 15 min	0.8%	20.5%
	From 15 to 30 min	0.0%	10.2%
	More than 30 min	0.0%	4.5%

In order to enhance the current PGI system, a smartphone parking application has been proposed especially the survey results revealed that the majority of the grages' users are expecting that this application will be useful in reducing parking search time and they will use it when it will be available.

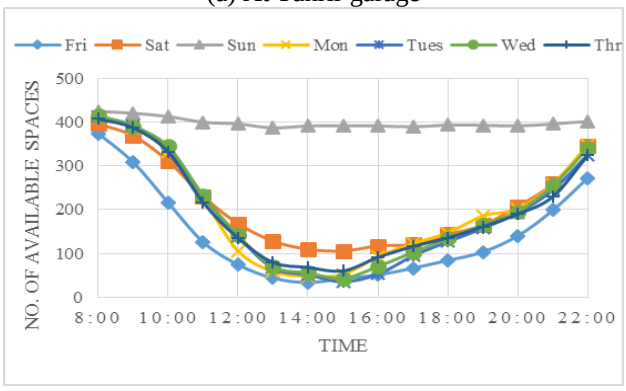
VI. PARKING OCCUPANCY MODELLING

As there were a general intention and willingness from the drivers to use a new or more advanced parking management system. The proposed smartphone application "**parking information**" can be used to provide users with the estimated number of available parking spaces in the studied garages in the current time. Also, it can be used to provide users with the estimated number of available parking spaces at the time the user will arrive at the garage or at any time that user specify whether in the same day or any other day based on the collected data concerning the time-varying occupancy. Hence the application can be considered as a traveler information tool that supports the traveler decision making before and during a trip.

As the proposed application would provide users by the estimated number of available garage spaces, it is necessary to investigate the parking occupancy pattern in order to develop models that can simulate the parking availability in each garage in all weekdays as well as in academic and summer vacation seasons. The data were collected in two seasons as mentioned previously. Figure 2 shows, for instance, the variation of available parking spaces with daytime for each weekday for **Tahrir** and **Attaba** garages in July (summer vacation season).



(a) At Tahrir garage



(b) At Attaba garage

Figure 2: Average of available parking space with time for each weekday within the summer vacation period

It can be noticed from these figures that the available spaces in Tahrir garage on Friday and Saturday are significantly low compared to other weekdays. This is because the garage is located in an area that includes a lot of governmental entities where their employees are usually on vacation on Friday and Saturday. On the other hand, the parking spaces in Attaba garage on Sunday is low compared to other weekdays. This is because the predominating activity in the area around the garage is commercial where the shops are on vacation on Sunday.

The time-varying occupancy data were also used in the calibration and validation of the developed models for estimating the number of available parking spaces at the studied garages over the daytime, 75% of the collected data were used in the calibration of models, while 25% were used in validation. For each of the eight garages and for different weekdays and for the two seasons (academic year and summer vacations), regression analysis has been used to calibrate the models that describe the relationship between the daytime and the number of available parking space. The coefficient of determination (R^2) has been used in testing the calibrated models, while for validation the following measure has been used:

- Mean absolute percentage error (MAPE):

$$\frac{1}{N}\sum_{t}\frac{|\hat{Y}_t - Y_t|}{Y_t}$$

Where Y_t and $\hat{Y}_t$ are the actual and estimated values of parking spaces, t is the time step, t =8/24 …22/24, N is the number of validation observations. Tables 2 and 3 show the calibrated models for eight garages for the two seasons, where Y is the number of available parking spaces and X is the time. As an example, if it is required to know the number of available parking spaces at 8:30 p.m. at Tahrir garage on Sunday at academic year season, then the model to be used is $y = -38596x^3 + 80481x^2 - 52377x + 11520$, X can be substituted by 20.5/24.Also shown in the tables R^2 and MAPE for the calibrated models for the eight garages for the two seasons.

As shown in the tables, the R^2 values range from 0.7 to 0.98. This reflects the accuracy of these models to be used in prediction of the available number of parking spaces. Also, it is noticeable that the calibrated models for the summer vacation period were with higher R^2 values compared with this of the calibrated models for the academic year values. This is because the variation in parking demand during the academic year period is higher than that during the summer vacation period.

As for the MAPE, the values range from 11.92% to 0.43%. Also, it is noticeable that the calibrated models for the summer vacation period were with lower MAPE values compared with this of the calibrated models for the academic year.

This models have been inserted as the database of the proposed system and cannot be seen by the user.

VII. SMARTPHONE APPLICATION DEVELOPMENT

The last step was to design an android application. Android Studio software has been used in designing the application. Figure 3 shows screenshots of the application interface.

The application main page displays the estimated number of available parking space for each garage in real-time. Also, in the main page, the user can select "options" in case he/she wants to know the estimated number of parking spaces at any garage at any time, selecting sound alert or to evaluate the application.

In order to display the available number of parking spaces at future time for any garage, the user can select "choose another time" option. Then, user can select any garage and select a day and time then select "show the number of parking spaces available".

For safety during driving, the user can select another option that enable the user to use a "sound alert" which provides sound messages about the number of available parking spaces at times the user has previously specified.

Also, the user can select any garage within the main page for more information such as capacity, location, and parking fees of the garage.

As mentioned previously, the last type of data was collected through feedback from the users of the developed application. 70 users have sent their feedback. The feedback analysis accentuates that 82% of users were satisfied with the application. Also, 89% of the participants agreed that the application helped them reducing parking search time with majority reporting less than 5 minutes reduction, the average reduction in parking search time was 8 minutes

VIII. RESULTS

The objective of this research is to evaluate the current parking management system based on drivers' opinion, and to develop and assess an Android application to be used on a handheld device running on the Android operating system. The main objective of the application is to provide the users by the number of available parking spaces in an easy way compared to the current PGI system of which the users experienced some drawbacks of it. The main advantages of the developed application include the possibility of knowing the parking spaces availability long time and distance before reaching the garage. In addition, since the parking spaces availability is dynamic in nature, the application can predict the parking situation at the time the user will arrive at the garage or at any time later in any of the weekdays and for two seasons (summer and academic). Furthermore, the application can provide these information for whole garages in the Cairo CBD area not only for limited number of garages as the case in PGI system.

As for the current parking management in Cairo, the Questionnaire data analysis showed that, the current PGI is well known by most of the drivers but they do not rely on it. The reasons may be that the VMSs are not working sufficiently as they went off many times and some of them are not clear enough to the drivers. Also, the majority of drivers do not know the locations of the VMS and the number of signs.

As for the developed application, the majority of the users stated that the application helped them reducing parking search time. The average perceived reduction in parking search time was nearly 8 minutes.

Table 2: The calibrated models, R^2 and MAPE for eight garages for the summer vacation season

garage	Day	Calibrated model	R^2	MAPE
Tahrir	Friday	$y = -9724.7x^4 + 23295x^3 - 19342x^2 + 6358.6x + 930.49$	0.94	2.07
	Saturday	$y = 12045x4 - 42223x3 + 51735x2 - 26166x + 6089.2$	0.80	1.14
	The rest of the week	$y = -18834x^4 + 4739.4x^3 + 43720x^2 - 38516x + 9604$	0.98	7.01
Opera	Friday	$y = 39724x^3 - 57861x^2 + 24477x - 2360.6$ (from 8:00 a.m. to 5:00 p.m.) $y = 89581x^3 - 207117x^2 + 159790x – 41076$ (from 5:00 p.m. to 10:00 p.m.)	0.98 0.98	0.92
	Saturday	$y = -23009x^4 + 60005x^3 - 51088x^2 + 14814x - 300.57$	0.98	4.05
	Sunday	$y = -35513x^3 + 72537x^2 - 45716x + 9150.7$	0.98	6.77
	The rest of the week	$y = -131249x^3 + 206412x^2 - 106442x + 18048$ (from 8:00 a.m. to 12:00 p.m.) $y = 3972.9x^2 - 4174.8x + 1089.2$ (from 12:00 p.m. to 10:00 p.m.)	0.98 0.98	3.14
Torgoman	Friday	$y = -240.82x^3 + 463.5x^2 - 269.88x + 379.53$	0.98	0.43
	Saturday	$y = -847.24x3 + 1909.9x2 - 1320.4x + 602.27$	0.95	0.83
	Sunday	$y = -3638.7x3 + 7496.9x2 - 4818.6x + 1256.8$	0.97	1.65
	The rest of the week	$y = -3780.4x^3 + 8179.2x^2 - 5478.5x + 1403.1$	0.98	2.37
Bostan	Friday	$y = 1873.1*x\text{^}3 - 3572x2 + 1984.4x + 510.41$	0.98	0.88
	Saturday	$y = 1214.4x3 - 1192.8x2 - 334.63x + 1074.9$	0.95	2.33
	Sunday	$y = 29150x3 - 35228x2 + 11680x - 255.04$ (from 8:00 a.m. to 4:00 p.m.) $y = 46792x3 - 116035x2 + 96042x – 25809$ (from 4:00 p.m. to 10:00 p.m.)	0.98 0.98	9.46
	The rest of the week	$y = -52232x4 + 119709x3 - 93088x2 + 27725x - 1888.3$	0.97	6.37

Hiliton	Friday	$y = -9731.4x4 + 24439x3 - 22211x2 + 8519.2x - 860.59$	0.87	1.88
	Saturday	$y = 11530x3 - 15385x2 + 6613.4x - 631.29$ (from 8:00 a.m. to 1:00 p.m.) $y = 66856x4 - 201917x3 + 226200x2 - 111294x + 20536$ (from 1:00 p.m. to 10:00 p.m.)	0.92 0.79	1.96
	Sunday	$y = -9657.6x4 + 21647x3 - 16362x2 + 4666.5x - 130.97$	0.71	8.12
	The rest of the week	$y = -434.29x^5 - 12220x^4 + 29410x^3 - 23369x^2 + 7164.9x - 463.1$	0.96	7.95
Falki	Friday	$y = 2003.8x3 - 3176.5x2 + 1236.1x + 10.107$	0.98	6.03
	Saturday	$y = 50182x5 - 155924x4 + 187087x3 - 106878x2 + 28367x - 2652.6$	0.95	5.83
	Sunday	$y = 14523x4 - 37232x3 + 35290x2 - 14669x + 2264.6$	0.94	5.74
	The rest of the week	$y = -59794x^5 + 198984x^4 - 259507x^3 + 165562x^2 - 51645x + 6312.8$	0.98	3.12

Table 2: continue

garage	Day	Calibrated model	R^2	MAPE
Attaba	Sunday	$y = 1867.2x4 - 5057.1x3 + 5195.7x2 - 2415.6x + 820.15$	0.87	1.63
	The rest of the week	$y = 46832x3 - 65444x2 + 28251x - 3466.2$	0.98	9.66
Omar Makram	Friday	$y = 109893x^5 - 336996x^4 + 399979x^3 - 228706x^2 + 62728x - 6127.2$	0.82	3.89
	Saturday	$y = 24341x4 - 72848x3 + 78691x2 - 35873x + 6133.7$	0.93	9.76
	The rest of the week	$y = 10377x^4 - 47958x^3 + 67677x^2 - 36711x + 6794.5$	0.98	9.64

Table 3: The calibrated models, R^2 and MAPE for eight garages for the academic year season

garage	Day	Calibrated model	R^2	MAPE
Tahrir	Friday	$y = -247125x^5 + 694338x^4 - 741716x^3 + 376565x^2 - 91889x + 10212$	0.72	9.83
	Saturday	$y = -8793x4 + 14415x3 - 3441.3x2 - 3543.1x + 2675.9$	0.79	3.25
	The rest of the week	$y = -38596x^3 + 80481x^2 - 52377x + 11520$	0.97	6.22
Opera	Friday	$y = 1853.2x3 + 3810.3x2 - 8108.1x + 3167.8$	0.95	10.37
	Saturday	$y = 7318.9x^3 - 6481.7x^2 - 1699.1x + 1926.6$	0.97	11.92
	Sunday	$y = -40463x4 + 67681x3 - 21821x2 - 9271.5x + 4101.6$	0.96	8.77
	The rest of the week	$y = 447134x^4 - 985275x^3 + 805786x^2 - 289966x + 38748$ (from 8:00 a.m. to 2:00 p.m.) $y = -21591x^3 + 52644x^2 - 40105x + 9776.6$ (from 2:00 p.m. to 10:00 p.m.)	0.98 0.98	5.07
Torgoman	Friday	$y = 17088x^5 - 56974x^4 + 73081x^3 - 44825x^2 + 13115x - 1139.5$	0.80	1.39
	Saturday	$y = 7290.9x4 - 18764x3 + 17907x2 - 7425.3x + 1429.2$	0.78	3.56
	Sunday	$y = 31723x5 - 104704x4 + 132659x3 - 79505x2 + 22204x - 1990.3$	0.90	4.39
	The rest of the week	$y = -2341.9x^3 + 5328.9x^2 - 3689.4x + 1064.6$	0.96	9.29
Bostan	Friday	$y = 3065.3x3 - 5451.3x2 + 2804.9x + 407.63$	0.90	2.66
	Saturday	$y = 1917.5x3 - 2458.5x2 + 424.54x + 893.77$	0.72	5.42
	Sunday	$y = -55034x4 + 123830x3 - 94129x2 + 27143x - 1662.1$	0.93	5.86
	The rest of the week	$y = -2341.9x^3 + 5328.9x^2 - 3689.4x + 1064.6$	0.96	9.29
Hiliton	Friday	$y = -1716.5x^4 + 4515.1x^3 - 4174.2x^2 + 1574.9x + 115.66$	0.85	4.78
	Saturday	$y = 4012.2x5 - 20629x4 + 34284x3 - 24835x2 + 8018.6x - 634.96$	0.88	2.73
	Sunday	$y = 27978x5 - 98913x4 + 133325x3 - 84564x2 + 24875x - 2408.9$	0.91	2.77
	The rest of the week	$y = 18627x^5 - 68806x^4 + 95334x^3 - 61170x^2 + 17896x - 1615.9$	0.97	3.08
Falki	Friday	$y = 44166x5 - 147211x4 + 191435x3 - 120231x2 + 35860x - 3929.5$	0.95	8.63
	Saturday	$y = 1038.7x4 - 5269.7x3 + 8215.4x2 - 5127.5x + 1119.5$	0.87	9.39
	Sunday	$y = -40229x5 + 142135x4 - 196478x3 + 132669x2 - 43724x + 5629.1$	0.91	8.16
	The rest of the week	$y = -55569x^5 + 188363x^4 - 250264x^3 + 162645x^2 - 51643x + 6410.8$	0.961	3.72
Attaba	Sunday	$y = -5450.8x4 + 10743x3 - 6624.4x2 + 1183.6x + 444.59$	0.74	2.24

	The rest of the week	y = -31449x4 + 75354x3 - 61176x2 + 18933x - 1466.3	0.95	8.84
Omar Makram	Friday	y = -55115x4 + 133284x3 - 114051x2 + 40487x - 4608.6	0.70	8.75
	Saturday	$y = -8912.4x^4 + 9336.8x^3 + 6331.7x^2 - 9236.4x + 2668.1$	0.91	5.93
	The rest of the week	$y = 14609x^4 - 57402x^3 + 75863x^2 - 40079x + 7347$	0.98	9.41

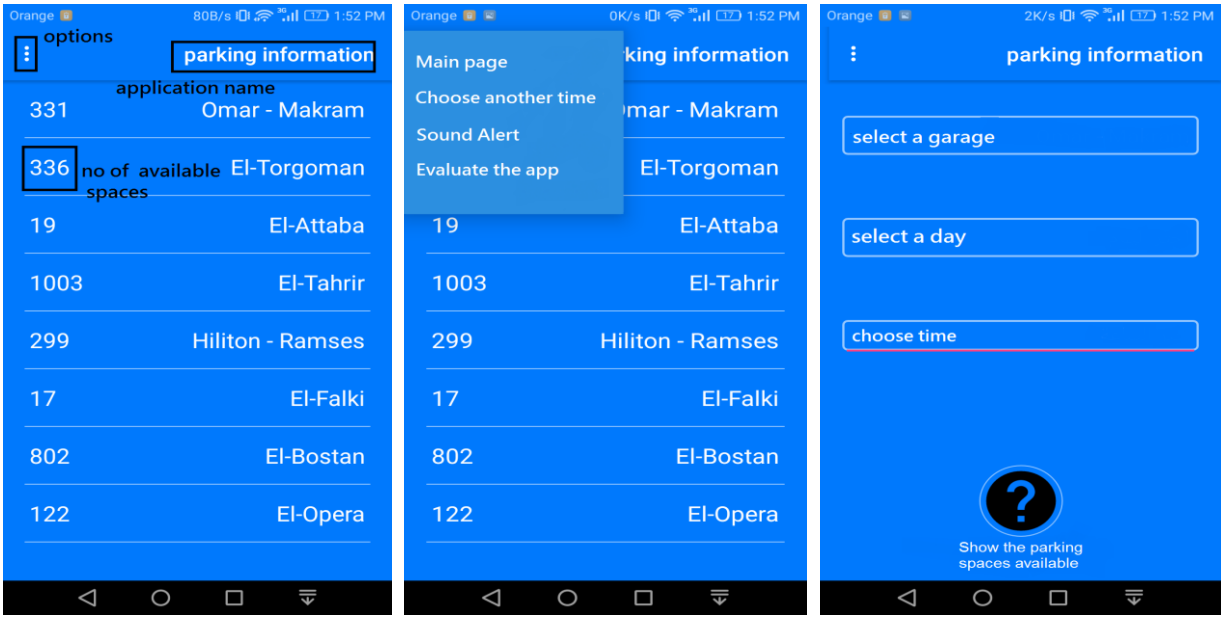


Figure 3: Screenshot examples of the developed application

IX. Summary, Conclusions and Recommendations

The parking information system has been implemented in Cairo city since 2015. The system provides on-line parking information for ten garages located at the city center through 14 Variable Message Signs (VMS). This research mainly aims to evaluate the efficiency of the implemented PGI system and to develop more advanced parking information system using smartphone application technologies and investigate its impact. A questionnaire survey interviews with a random sample of drivers at the studied garages have been carried out.

The survey data analysis showed that nearly 46% of the participants cannot find available parking space easily in the City Center, the lost time ranges from 5 minutes to more than 30 minutes with an average of 16 minutes. The PGI is well known by most drivers. However, not many of them rely on it to determine the garage in which they will park. the main purpose of this is that the VMS are not working sufficiently as they went off many times and some of them are not clear enough to the drivers, as there may be an obstacle that prevents vision (like the sign located at Adly street). Despite the fact that PGI system is well known by most of drivers, the majority of them do not know the locations of the VMS and the number of signs.

A comparison between drivers who are using the PGI and those who do not, showed that drivers with shopping and entertainment purpose are the largest with percent (8.6%) in using the PGI system, while drivers with working purpose are the smallest percent, also it is noticeable that the major users of the system are drivers who are not frequently visiting the City Center. It also showed that the average parking search time for drivers using the PGI was about 6 minutes and about 18 minutes for drivers who do not use the PGI.

In order to enhance the PGI system, improving the service provided, providing the garages with sufficient regulatory signs and other facilities such as elevators, removing obstacles that prevent vision, raising the public awareness of the current PGI system are recommended, other garages with high demand are recommended to be serviced by the PGI system.

As the VMS is a primary tool in disseminating information but the number of screens to be available is limited as it costly in terms of construction and periodic maintenance. A smartphone parking application has been proposed. The last part of the questionnaire survey includes questions about the proposed application that will help in expecting its success before deployment, 99% of the participant agreed that the application will be useful and it will help in reducing parking search time, the average expected reduction in search time was about 9 minutes.

The main objective of the application is to provide the users by the number of available parking spaces in an easy way compared to the current PGI system of which the users experienced some drawbacks of it. The main advantages of the developed application include the possibility of knowing the parking spaces availability long time and distance before reaching the garage. Historical data has been used in calibrating and validating models which describe the relationship between the time and the available number of spaces for each garage for each day of the week. After the application deployment, 70 users have sent their feedback.

The feedback analysis accentuates that 82% of users were satisfied with the application. Also, 89% of the participants agreed that the application helped them reducing parking search time with majority reporting less than 5 minutes reduction, the average reduction in parking search time was 8 minutes. Accordingly, it is recommended to widely use the provided smart parking application due to its shown benefits. In addition, it is recommended to cooperate with Cairo governorate to provide an in-time number of available parking information in addition to the expected numbers in the future based on the developed models.

REFERENCES

1. E. I. Vlahogianni, K. Kepaptsoglou, V. Tsetsos, and M. G. Karlaftis, "Exploiting new sensor technologies for real-time parking prediction in urban areas," Transp. Res. Board 93rd Annu. Meet. Compend. Pap.2014, pp. 1–19.
2. D. Shoup, "Cruising for parking," Transport Policy vol. 13, no 6, 2006, pp. 479–486, 2006.
3. X. Ni, D. Sunand and L. Zhang, "Study on parking variable message sign display problem: a discriminated release strategy with space occupancy indicator," Transp. Res. Board 94th Annu. Meet.2015.
4. T. Giuffrè, S. Marco, and G. Tesoriere, "A novel architecture of parking management for Smart Cities," Procedia - Soc. Behav. Sci., vol. 53, 2012, pp. 16–28.
5. D. Teodorović and P. Lučić, "Intelligent parking systems," Eur. J. Oper. Res., vol. 175, no. 3, 2006, pp. 1666–1681.
6. S. Y.; Cheung and P. P. Varaiya, "Traffic surveillance by wireless sensor networks : Final Report," Doctoral dissertation University of California, Berkeley, 2006.
7. L. E. Y. Mimbela and L. A. Klein "Summary of vehicle detection and surveillance technologies used in intelligent transportation systems Federal Highway Administration s (FHWA) Intelligent Transportation Systems Joint Program Office" 2000.
8. K. E. Kinyanjui and A. M. Kahonge, "Mobile phone–based parking system," Int. J. Inf. Technol. Control Autom., vol. 3, no. 1, 2013, pp 23–37.
9. K. W. Axhausen, J. W. Polak, M. Boltze, and J. Puzicha, "Effectiveness of the parking guidance information system in Frankfurt am Main," *Traffic Eng. Control*, vol. 35, no. 5,1994, pp. 304–309.
10. M. Gallo, L. D'Acierno, and B. Montella, "A multilayer model to simulate cruising for parking in urban areas," Transp. Policy, vol. 18, no. 5, 2011, pp. 735–744.
11. F. Caicedo, F. Robuste, and A. Lopez-Pita, "Parking management and modeling of car park patron behavior in underground facilities," Transp. Res. Rec. J. Transp. Res. Board, vol. 1956, no. 1956, 2006, pp. 60–67.
12. M. Patil and R. Sakore, "Smart parking system based on reservation," vol. 2, no. 6, 2014, pp. 21–26.
13. N. Moini, D. Hill, R. Shabihkhani and H. Homami, "Impact assessments of on-street parking guidance system on mobility and environment.," in Transportation Research Board 92nd Annual Meeting., 2013.
14. M. McDonald and K. Chatterjee, "VMS in urban areas-Results of cross-project collaborative study," Technical Report TR1101 D3.3.1-a, Transport Sector of the Telematics Applications Programme (T-TAP), vol. 3, no. 1, 2000.
15. S. Nawaz, C. Efstratiou, and C. Mascolo, "ParkSense: A Smartphone Based Sensing System For On-Street Parking." In Proceedings of the 19th annual international conference on Mobile computing & networking, 2013 (pp. 75-86) ACM.
16. T. Fabusuyi, R. Hampshire and V. Hill. "Evaluation of a smart parking system". Transportation Research Record: Journal of the Transportation Research Board, (2359), 2013, pp.10-16.
17. Y. Geng and C. G. Cassandras, "Dynamic resource allocation in urban settings: A 'Smart Parking' Approach,". In 2011 IEEE International Symposium on Computer-Aided Control System Design (CACSD), 2011, pp. 1-6. IEEE.
18. Y. Geng and C. Cassandras, "New 'Smart Parking' system based on resource allocation and reservations," IEEE Transactions on Intelligent Transportation Systems, vol. 14, no. 3, 2013, pp. 1129–1139.