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# Smart parking :an efficient approach to city's smart management and air pollution reduction

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**ABSTRACT:**

**Introduction:** Due to increasing the population of cities and the physical-spatial expansion of the cities, vehicles are being used progressively, which has caused many problems for the cities including traffic increase, chaos in finding urban parking lots, increase of environmental pollution, decrease of citizens' satisfaction, and so on. Among the many urban problems, parking lot is one of the issues that has been heavily debated in recent years. The lack of sufficient number of parking lots, on the one hand, and the related disorder and management problems, on the other hand, have led to a range of managerial and environmental problems. Meanwhile, one of the paradigms that has focused on this issue in recent years is smart city paradigm, which has offered the smart parking. This paradigm believes that parking, as a part of the city's space, can be smart and can help urban management.

**Materials and methods:** This is an applied research in terms of purpose and a descriptive-analytical research in terms of nature. The required data were collected using documentary and field studies and SWOT method was used to analyze the data.

**Results:** This study was conducted to evaluate and investigate the role of smart parking in increasing the efficiency of urban management and its impact on reducing air pollution.

**Conclusion:** Finally, the conclusion of the research have led to key strategies for achieving the research goal.

## Introduction

With the increase in population in metropolises and the spatial-physical expansion of cities, the use of vehicles is increasing [1]. This issue, especially in developing countries that do not have a systematic public transportation system, has had a major impact on the inter-urban transport network and has increased the use of personal vehicles [2]. Meanwhile, the use of personal vehicles has led to a range of environmental, traffic, congestion and the like for cities, and has greatly affected the level of citizens' satisfaction. However, we still see an increase in the number of vehicles in urban areas. The number of new cars that are being counted in some Iranian cities can be mentioned in this regard. For example, according to the annual statistics, more than 300 thousand new vehicles in Tehran [3], 144 thousand

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new vehicles in Isfahan [4] and similar number in other cities are registering their plates. However, the capacity of each of these cities can withstand a certain number of these cars. For example, Tehran has a capacity of 750,000 vehicles a day, while more than 4 million vehicles (six times the city's total capacity) travel daily in the city and create an enormous amount of pollution. According to studies, more than 80% of air pollution of cities such as Tehran is due to mobile resources or vehicles [5].

These issues are more critical when the lack of infrastructure for managing these spaces is witnessed. In this regard, one of the infrastructure that is less seriously considered but can play an important role in urban transport management is the issue of parking [6]. Parking is one of the important parameters in the planning of a highway transportation system, because according to studies, a vehicle is used for a period of 400 h during a year, while it stays in park mode for 95% of the year [7]. This point determines the role and place of parking in our daily lives. However, the lack of parking space, the lack of parking management and the resulting turmoil have affected the landscape and urban management.

This is particularly evident in the main parts of cities which have various land uses and attract more cars and higher traffic loads [6]. Meanwhile, one of the most important factors that can affect this issue is the lack of parking spaces in the periphery of these areas, which has recently become a major constraint for urban management; this has caused a major number of cars to be parked at the sides of streets [1]. However, vehicles parked on the margins of the streets without special management, especially in the central area of the city, reduce capacity, cause landscape turbulence, slow down the speed, increase accidents and reduce safety levels in these passages [8]. This is a critical issue when some vehicles occasionally have to patrol persistently in order to find a possible parking space, if any [9]. Finally, if they do not find the right place, they may choose to double park, sometimes triple park, and narrow down the route, which can increase traffic, accident, pollution and the like. In fact, with the increase in the number of cars in towns and the reduction of parking spaces, locating a place to park in the city has created a lot of challenges and difficulties for the urban management system and the comfort of the citizens, and the bigger the cities, the more challenging this problem will be. Likewise, it is possible to mention Tehran metropolis, which is a collection of traffic and parking disturbances and challenges. According to the studies, more than one million vehicles daily spend between 15 and 35 min to find parking in Tehran [10].

Therefore, the necessity of paying attention to the management of urban parking has become one of the most important issues in many organizations, companies, commercial centers, public parking lots, and residential buildings. Therefore, new approaches shall be considered for collecting information and optimizing parking management as well as providing faster, easier and more secure access to the site, avoiding waste of energy and environmental protection.

In this regard, it is possible to point out the smartization of cities, which has emerged as a new approach to urban spaces. This approach focuses on smartization of various dimensions of cities [11], and according to this approach, it also deals with smartization of parking lots and considers it as an important parameter for more smartization of urban spaces; it also believes that smart parking can reduce a part of urban transportation problems and can be turned into a source of revenue for urban management. In this regard, a study was conducted in the city of Ghent, Belgium, proving

that if smart parking was deployed, the city's revenue from parking tickets and fines was 10 times higher than the cost of deploying smart parking systems [12].

Meanwhile, in addition to the economic benefits, smart parking facilities provide an opportunity to increase resource's efficiency and parking spaces in the city by reducing the search time, thus managing a part of parking problems, traffic congestion and air pollution. In this regard, one of the operational strategies to achieve this is that drivers are already aware of the availability of parking space around their destination [13]. The smart system reduces the cost of managing these places, air pollution, and solves the problem of finding empty space, and subsequently provides the standard conditions for the citizens by providing citizens with information regarding the parking lots and guiding them towards those predefined parking spaces.3. In fact, with these approach, smart parking lots are an inevitable part of urban life, and this necessitates the need to pay attention to these types of parking lots [14]. Therefore, in this study, considering the necessity of paying attention to modern technologies to achieve smart and sustainable cities, the role of smart parking in improving the efficiency of urban management as well as reducing air pollution has been emphasized; the necessity of paying attention to this issue has also been highlighted and needed strategies have been developed to achieve the set objectives.

***Review of the related literature***

Parking is a part of the urban land that is considered for vehicles' stop. Traffic engineers consider parking as one of the main uses of land, which has a more significant role as urbanization has increased [15]. Parking coordinates and sets the use of land and transportation in the urban area, and is one of the most important assets that leads to increased city incomes [6]. In general, city-level parking lots can be divided into the following types as indicated Table 1. The important point about existing parking lots is the lack of management of these parking lots and their traditional structure. In fact, most of these parking spaces do not have any standardized system for parking information, and the management of these spaces is heavily dependent on human and physical space and has a very low performance. This affects the city and traffic situation and its pollution. Based on surveys, about 30% of traffic in cities is due to find a street park location and search the petrol stations [16]. It's a waste of time for many people, and if we consider the lost hours in terms of fuel consumption, $CO_2$ emissions and economic impact, we find that finding a parking lot is very costly for the individuals, the public and the environment [17]. In many developing countries, the periphery of the streets has become a place for parked cars, and their lack of management has increased traffic and air pollution.

Indeed, the fact that marginal parking lots are free of charges and non-payment for parking on the streets' sides has increased the daily travel of private cars and the long-term use of marginal parking. In fact, a major part of this issue must be attributed to the management structure of these locations [9]. Accordingly, today in some countries, parking management is recognized as one of the most important parameters in urban management because it can affect traffic efficiency and urban quality of life. Considering this approach, transportation policy makers in recent years have paid more attention to parking and have called it a potential mechanism for addressing traffic congestion and reducing air pollution at the city level. In fact, the distance to reaching a parking space, the time taken to search for park-

Table 1. Different types of parking lots in cities

| Types of parking Lot | Definition | Explanations |
|---|---|---|
| Street parking | Vehicles use street sides as parking lots | Use of this type of parking is appropriate when the number of vehicles in the city is low relative to the capacity of the streets. In cases where street capacity is not responsive to vehicles, traffic management is very important for using street sides as parking spaces. |
| Surface parking lot | Surface parking lot a land, which, regardless of its shape, can be used as a parking lot. | In these parking lots, the basic rules of the parking design should be observed, in such a way as to maximize the use of available land. |
| Multistory parking lot | It is a kind of parking lot which maximize the use of land based on the number of floors. | In areas such as city centers where land is scarce and valuable, or in the vicinity of large airports and public passenger terminal stations, where a fairly large number of parking spaces is needed, creating surface parking lots is not cost-effective and multistory parking lot are used. |
| Roof parking lot | Using buildings' roofs as parking lots, in which case necessary predictions in building design and calculations must be made. | it is used in areas where land is scarce and expensive, and independent parking is not feasible and affordable. |

ing and the distance between the car park and the intended destination have a significant impact on parking management [18]. In this regard, one of the paradigms that deals with parking management by a new approach and attempts to address important parameters in parking management is the smart city paradigm [11]. In this paradigm, smart urban parking is emphasized and the focus is on providing facilities and equipment for car parking and traffic management system [19].

In fact, the approach taken in smart parking is to use electronic devices and artificial intelligence to increase the welfare of citizens and increasing their satisfaction in this regard. In other words, the importance of smart parking is more evident after the spread of smart phones, the internet of things, and the development of artificial intelligence and has been considered seriously [13]. Meanwhile, dimensions of the internet of things have entered the domain of smart parking lots using a network of affairs, including sensors, actuators and RFID technology, and provide significant services to its users and is expanding ceaselessly [20]. This trend will undoubtedly dominate the cities in the near future.

However, despite the increasing attention to smartization and the need to focus on its role in shaping future cities, this issue is still underestimated in many developing countries, including Iran, in such a way that the theoretical and experimental vacancy in this area is quite evident. In this regard, this article is among the

very few articles that have addressed this issue.

## Materials and methods

This is an applied research in terms of purpose and a descriptive-analytic study in terms of its nature. Documentary sources and field studies have been used in order to collect information and data and we have considered the general situation of parking lots and the potential of smart parking lots. SWOT method was used to analyze the data. In order to evaluate internal and external factors in the framework of two internal and external factors evaluation matrices, (IFE) and (EFE), respectively, necessary measures have been taken. The strengths, weaknesses, opportunities, and threats were gathered using expert opinion, which included a total of 20 people. Initially, factors in the four components were determined by the experts, then by using a questionnaire, the experts' opinion was gathered and the average of the views of the experts on each factor was determined by its score. In other words, the factors determined by the experts at the next stage were weighted in the form of questionnaire's items and the average of the answers to each questions related to each factor was regarded as the score of that factor. In the next step, in order to evaluate the external and internal factors for each factor, a weight coefficient between zero (not significant) and one (absolutely significant) was assigned so that the sum of the assigned weight coefficients equals to one. Finally, the related strategies were extracted by considering the highest coefficients and were adjusted in the form of tables.

## Results and discussion

### *The basis of the smart parking system*

Smart parking is an inevitable part of the city's life. With the increase of cars in cities and the reduction of parking space, finding a location for the maintenance and parking of cars in the city has led to many hardships and challenges (especially in crowded places and commercial or cultural centers) [21].

In such a situation, the formation of smart parking lots has contributed tremendously to the traffic management system and the urban car park. These parking lots are expanding progressively using the modern technologies are trying to adapt themselves to the needs of the day [10]. Smart parking lots, devices and sensors connected to each other with the help of the internet of things can help automation of smart parking of cars [13]. Accordingly, a smart parking management system can be considered as one of the most important factors in reducing traffic and producing and releasing carbon in the city. In this system, information is collected instantaneously from all parking spaces and through ultrasonic detectors mounted on top of each parking cell, and then transmitted to the main processor through the controls of each zone. The main processor, after data processing, sends information of each space to its specific display, in order to guide the car by informing the location and the number of available spaces. This information is also transmitted to the main computer and stored in the original server memory. And based on the needs, the parking manager can view and use the parking information instantaneously, monthly, or annually.

The smart management system enables drivers to get real-time information from the parking lot, and use them based on their timetable, without having to spend time and money to patrol and search vainly in the city. In addition, these types of parking lots allow drivers to travel more easily by accessing instantaneous parking information via their smartphone [10].

Full and accurate information on the number of cars in the parking lot, increasing the safety factor of the vehicles at the moment of traffic, entering and leaving and stopping, reducing the number of

involved personnel, increasing the level of safety, and receipt of costs, automatically or manually provide a more comprehensive management for parking lots [17]. In the smart management system of indoor parking uses equipment such as roadblock gateways, vehicle checked-in sensors, direction sensors, height sensors to prevent the entrance of vehicles with unauthorized altitudes, video-recording cameras (to identify car plates and drivers), etc. The ultimate goal of smart parking management system is to reduce the distance for cars and increase the number of parked cars in the space, and most importantly, the beneficial use of time and cost [10]. In general, some of the objectives of the parking management system, and in particular smart parking management, can be found in Table 2.

***Establishment of smart parking system***

Establishment of the system is the main task of service providers. Establishing parking system is divided into five sections:

1) Software system
2) Hardware system
3) Deploying smart tools at the local and regional level.
4) Collecting and anticipating data
5) Payment

***A. Software system***

The software system is the interface between information and users of the system, which allows the access to parking lots for the audience by using smartphones. Several work starts with the development of a software system for the smart parking system based on wireless sensor network (WSN). WSN provides identifiable information for the smart parking system and needs to be well managed to respond to a driver's request for parking [13]. In this regard, numerous applications are being developed and presented among the people, thereby increasing the range of users of parking finder software.

***B. Hardware system***

The most important hardware to be considered in smart parking lots can be the sensors and cameras used in the desired areas. The smart parking guidance system operates on the performance of sensors that can detect free space and send data to backup systems. The backup systems, based on this information, transmit information to users' software or the notification system. Today, two types of sensors are used in smart park systems: 1) Ultrasound sensors; 2) Magnetic sensors. Ultrasound or ultrasonic sensors or sensors that work like sonography sensors are used

Table 2. Some of the goals of parking management and inclination towards smart parking lots

| | |
|---|---|
| 1 | Full and accurate information on the number and location of |
| 2 | vehicles in the parking lot at the moment |
| 3 | Increase vehicle safety at the moment of traffic, |
| 4 | arrival, departure and stop |
| 5 | Reducing energy consumption, saving and managing consumption |
| 6 | Providing value added services to customers |
| 7 | Providing an integrated solution in line with the goals of smart city |
| 8 | Receiving fees automatically or manually |
| 9 | Reducing the involvement of human resources |
| 10 | Reducing maintenance costs |
| 11 | Increasing safety |

for applications such as indoor parking. These ultrasound sensors send sound waves in the range of 25 to 50 kHz, which goes beyond the perceptible sound range of humans. The diagnostic sensors are connected to the control terminal via the RS485 cable or wireless connection (433 MHz), and the terminal will communicate with the control center through the usual internet connection.

For parking on the side of city streets, sensors which are powered by batteries and are among the magnetic detectors are used. These sensors are buried in the ground floor of the parking space. These sensors can detect a range of -1200 μT to +1200 μT. Output data will be in the range of 1. 563 to 800 Hz, which can be considered differently by users for each sensor. Tμ is a very small criterion used to measure the magnetic field. Magnetic sensors find out whether there is a card parked above the ground on them according to the metallic objects and surrounding magnetism. The magnetic sensors can continue to operate at a temperature range of 40 degrees below zero to 85 degrees above zero. In addition to these sensors, another technology, such as infrared, is also useful for increasing the accuracy of magnetic sensors.

One disadvantage of magnetic sensors is that they are easily affected by environmental factors. For example, a large piece of metal near them, various types of magnetic disturbances, a compact mass of cement or asphalt on a sensor that is quasi-magnetic, or any other factor that can create a magnetic state will negatively impact the performance of these magnetic sensors. Smart parking company also uses IR sensors along with diagnostic sensors to reduce the error rate.

In addition to the sensors, it is possible to mention radar cameras that are used in some countries, including Germany, and are considered as a tool for smart management of marginal parking. But the main problem with this type of technology is its cost and its performance radius. This has led to the emergence of a newer approach known as the visual and objective cameras which attempts to fill the gap between radar and sensor car parking systems; we will discuss and explain it in a separate article in more details.

***C. Location selection and deployment of tools***

The third step should be to select the suitable venues for the creation and expansion of smart parking lots. After some decades and vehicle growth and lack of parking space and ultimately the high cost of increasing parking facilities, accurate assessment of parking management and locating of parking lots has become essential [21]. At this stage, it is necessary to identify areas of the city that are special in terms of congestion and urban traffic volumes and the traffic of vehicles, and the following measures which include the necessary encodings to deploy the sensors or cameras, the internet infrastructure, etc. shall be taken.

In order to achieve this goal, parts of the city must first be identified as the initial pilot in order to carry out the necessary trial and errors in the target area. Consideration should be given to the selection of this area as it is the first step in the work, and in the event of a problem, the result of the work will face a serious problem. For example, if in a region of the city which has a significantly weak cultural or financial level but has significant number of markets and always has a high traffic volume, smart parking lots are established which need payment and is unprecedented in that place, it might lead to turbulence and can even form protests. In addition, it can bring severe losses to the investor company because people can destroy the relevant infrastructure and cause a lot of problems for the investor company. As a result of this phase, the initial phase of the work will play

an important role in the future of smart parking (in particular smart marginal parking).

***D. Data collection and processing***

In order to collect data from smart parking lots, the structure of internet of objects should be used. In this system, all physical objects (including sensors, cameras, cloud-based servers, and mobile phones) are connected together via the Internet [13] and use Radio-Frequency Identification (RFID) technology. This technology is used to detect vehicles. For this purpose, the necessary information must first be collected and evaluated. This is done either through sensors, cameras, or through audiences and users of smartphones; each of these cases are analyzed in the following section [22].

***Sensor-based Information Evaluation:***

Usually this information is collected through two fixed and movable sensors. In fixed state, the sensor has the ability to measure the presence and absence of vehicles in parking lots. When the occupancy status changes, the sensor can detect the presence or absence of vehicles and update the information in a short time. In the second type, movable sensors, the vehicle's motion is used to collect information along the way with smaller sensors that can detect occupancy when it passes through the parking lot, so information may be updated for a long time [23].

In the meantime, a variety of sensors can be used including infrared sensors, temperature sensors, ultrasound sensors, magnetic sensors and the like [22].

Ultrasound sensors are used for roofed parking areas, but they are sometimes used in open spaces to detect the vibration of the ground from the car park and to determine that the parking space is occupied by the vehicle because the vehicles are the heaviest objects in urban spaces [24]. In fact, these sensors transmit sound waves in the range of 25 to 50 kHz, which exceeds the comprehensible sound level of humans. The diagnostic sensors are connected to the control terminal via a RS485 cable or a wireless connection (433 MHz), and the terminal will communicate with the control center through the usual Internet network, thereby collecting data.

In addition to these types of sensors, infrared sensors can also be mentioned. These sensors receive heat from the human body and are often used together with other sensors. The sensitivity of these types of sensors to light and any environmental objects has reduced the accuracy of their operation [25] and [26]. Often, ultrasound sensors are also used together with infrared sensors. In fact, ultrasound sensors use sound instead of light for outdoor space, and it works better. The ultrasound sensor provides a more sophisticated signal pattern with the possibility of multiple detection at fixed or mobile frequencies [27] and [28].

But the most commonly used sensors in urban spaces and for the management of side street parking are magnetic sensors. These sensors are positioned on the ground and provide the energy they need from the battery they are fitted to. The magnetic sensors can detect in a range of -1200 µT to +1200 µT. Output data will be in the range of 1.563 to 800 Hz, which can be considered differently by the user for each sensor. This sensor measures the current magnetic field and detects the entrance of large metal objects.

***Data collection via camera and audio sensors:***

Using these tools provides a much more complex signaling pattern than ultrasound [29] and [30]. Both of them require image processing and audio tracker to extract information from background sound. This is more acceptable because it provides additional information related to criminal scenes or privacy of individuals, and the possi-


Fig. 1. Ultrasonic and magnetic sensors in parking lots

bility of retrieving important information, especially in case of crime.

The induction loop and piezoelectric sensors are both interconnected and mounted on the road surface. The induction loop is a mature technology and is widely used to monitor traffic and simply detects vehicle traffic [35, 55]. The piezoelectric sensor is similar to the inductive loop, but it can read more information than the pressure applied to it. This type of sensor requires an intrusive installation and is easily used due to its frequent application.

***Smart crowdsensing:***

One of the functions that comes with mobile phones is informing others about the location of the car park. This is done when a user attempts to find a parking lot using the parking locator software. So, after completing the use of parking and paying for a place through a mobile phone, the software informs others about the vacancies and thus contributes to the parking lot [17]. In fact, measuring and collecting data through a variety of sensor devices (for example, smartphones) by a mass of users, with the aim of sharing data collected from parking spaces with citizens of smart city is through a common ICT platform for the welfare of the community. A new type of crowdsensing is designing a smart parking design that encourages users to share information [31].

***E. Payment***

This step can be considered the last step in smart parking lots. At this stage, people will pay after using the parking space. This can be done through a bank card, park meter, online and software. For example, park meters can be a tool for collecting data and paying for known items in this field. In fact, a parking meter is a device used to collect money and pay for a car park at a specific location for a limited time. Parking meters are installed and run by municipalities as a means of implementing seamlessly urban traffic road management plans that may have commercial goals and revenue as well [32]. By increasing the sensors of the wireless sensor network (WSN), the parking meters prove useful, creating a connection between drivers and parking data; by using WSN technology, parking meters are often known as amplifiers for parking sensors [33].

In addition to parking meters, today, with the expansion of information and communication technologies and the expansion of the scope of use of smartphones, the application of parking locator software is growing increasingly. The software has several capabilities, one of which can be considered in online payments, facilitating the payment and managing time. Along with

these methods, the traditional methods can also be mentioned that are still in progress in many parking lots.

***Research finding***

*Extracting internal factors (strengths, weaknesses) and external factors (opportunities, threats)*

The necessity of paying attention to the parking locations is increasing progressively. Accordingly, knowing the importance of these places in the urban management system and their role in different aspects of the city has given more attention to this urban issue. To clarify the importance of this issue, it has been tried to extract the most important strengths, weaknesses, opportunities and threats according to the interviews with experts in the field of transportation and urban management, and the results are indicated in the following tables.

Table 3.The strengths of smart parking lots from the perspective of experts

| | |
|---|---|
| **Strengths** | - Increasing the municipalities income (paying attention to it as a sustainable income for municipalities)<br>- Reducing human-based controls and monitoring costs and reducing the level of human error in parking management<br>- Raising the quality of life of citizens<br>- Increasing urban management capability in urban parking management<br>- Ability to control vehicle traffic and simultaneously managing multiple entry and exit barriers by comprehensive parking management system<br>- Improving urban management capability in urban landscape management (with the management of regular parking)<br>- Creating new knowledge-based job opportunities<br>- Automatic control of entry and exit by imaging cameras<br>- The possibility of instantaneous reporting of public parking (empty and full capacity, specifications of vehicles in the parking lot, etc.)<br>- Ability to add facial recognition and coordinating the equipment with it<br>- Reducing costs and increasing revenue<br>- Managing internal traffic<br>- Further parking safety coefficient<br>- Reducing parking time for drivers<br>- Decreasing part of the traffic caused by searching for parking spaces<br>- Reducing fuel consumption and consequently reducing environmental pollution<br>- Reducing the cost of air conditioning for covered parking lots<br>- Facilitating the search of a parked car<br>- Ability to create a blacklist and no-entrance permission for some cars along with software alarms<br>- Using artificial intelligence to identify high-emission vehicles and reporting and managing their traffic in the city.<br>- Ability to match the photo by the operator when entering and leaving to prevent theft and misuse<br>- Possibility to use your parking system without computer<br>- Online communication and network operation |

Table 4. The weaknesses of smart parking lots from the perspective of experts

| | |
|---|---|
| **Weaknesses** | - Weakened knowledge about the capabilities of the smart city<br>- Lack of specialist knowledge about smartization of parking lots<br>- The high cost of smartization infrastructures<br>- Lack of smartization infrastructures<br>- Weaknesses in the use of the private sector and their capabilities<br>- The lack of smart parking software<br>- The simplicity of existing software and their weakness in attracting users<br>- The prevalence of sensor-based parking and the possibility of error and misdiagnosis and misleading information to users.<br>- Low sensitivity and low resistance of sensors to weather conditions and poor performance in these cases where traffic may be even higher (rainy, snowy, or very hot weather)<br>- The high cost of using some of the sensors and networks, including the imaging camera in smart parking management |

Table 5. The most important predicted opportunities of smart parking lots from the perspective of experts

| | |
|---|---|
| **Opportunities** | - The formation of the new paradigm of the smart city in the world and the need to pay attention to it in Iran<br>- The formation of smart cities organizations<br>- Formation of a part of the infrastructure necessary for smart city<br>- Artificial intelligence growth in cities<br>- Attention to the smart public transport approach in cities<br>- Increasing the use of smartphones by people<br>- Internet availability at city level<br>- Increasing people's knowledge about online services<br>- Increasing the use Internet of objects in the city<br>- Increasing use of smart apps<br>- The possibility of online communication through urban software and applications in different areas<br>- The lucrative nature of this technology and the presence of investors from private sector to invest in this area |

Table 6. The most important predicted threats of smart parking lots from the perspective of experts

| | |
|---|---|
| **Threat** | - Theoretical and scientific vacancy related to the issue of smart parking (especially in Iran)<br>- The lack of support or minimal support for creative ideas of this field<br>- Lack of specialized staff in the field of smartization<br>- lack of variety of software available at the community level and the weakness of the software for smart parking<br>- Lack of necessary knowledge on the use of minimal software available (concerning parking lots)<br>- The citizens' ignorance of how to use the apps<br>- The lengthy process of designing and training how to use smart parking system applications<br>- The weak urban infrastructure needed to use some smart parking management systems<br>- High cost of smartization<br>- The possibility of abuse of spatial and temporal information of real and legal persons by installing sensors or smart cameras (security threats) |

*Analysis of internal factors (strengths, weaknesses) and external factors (opportunities, threats)*

After extracting the necessary data, we begin the second stage. At this stage, with the help of the experts, considering the importance of each component and comparing these components together, the importance coefficient of between zero and one is assigned to that component and is entered in the third column of the table. The value of these coefficients must be such that their sum equals to one. In the fourth column, strengths are ranked 4 or 3 considering that whether they are excellent or normal, and the weaknesses are ranked 1 or 2 considering that whether they are serious or normal. If the sum of total score of the internal factors in this table is more than 2.5, the strengths ahead will overcome the weaknesses, and if this score is less than 2.5, it would indicate that the weaknesses will overcome the strengths [34]. The results of internal factors analysis are presented in Table 7. According to the results, the most important strengths of smart parking lots should be the increase in municipalities' revenue levels, reduction of traffic, reduction of search time for the parking space and reduction of fuel consumption, which is the highest coefficient based on the experts' opinions. All these factors have received 0.16. However, the main weaknesses of these parking lots should be in the weakness of knowledge and understanding of the capabilities of smart parking lots, the high cost of infrastructure and the lack of trust of private sector organizations to enter this field, all of which score 0.08.

Table 7. Internal factors analysis from the perspective of experts

| Row | Strengths and weaknesses | Coefficient | Score | Final score |
|---|---|---|---|---|
| S1 | - Increasing the municipalities income (paying attention to it as a sustainable income for municipalities) | 0.04 | 4 | 0.06 |
| S2 | - Reducing human-based controls and monitoring costs and reducing the level of human error in parking management | 0.02 | 3 | 0.12 |
| S3 | - Raising the quality of life of citizens | 0.03 | 4 | 0.09 |
| S4 | - Increasing urban management capability in urban parking management | 0.03 | 3 | 0.09 |
| S5 | - Ability to control vehicle traffic and simultaneously managing multiple entry and exit barriers by comprehensive parking management system | 0.03 | 3 | 0.09 |
| S6 | - Improving urban management capability in urban landscape management (with the management of regular parking) | 0.02 | 3 | 0.06 |
| S7 | - Creating new knowledge-based job opportunities | 0.02 | 3 | 0.06 |
| S8 | - Automatic control of entry and exit by imaging cameras | 0.03 | 4 | 0.12 |
| S9 | - The possibility of instantaneous reporting of public parking (empty and full capacity, specifications of vehicles in the parking lot, etc.) | 0.03 | 3 | 0.09 |
| S10 | - Ability to add facial recognition and coordinating the equipment with it | 0.02 | 3 | 0.06 |
| S11 | - Reducing costs and increasing revenue | 0.03 | 4 | 0.12 |
| S12 | - Managing internal traffic | 0.04 | 4 | 0.16 |
| S13 | - Further parking safety coefficient | 0.03 | 4 | 0.12 |
| S14 | - Reducing parking time for drivers | 0.04 | 4 | 0.16 |
| S15 | - Decreasing part of the traffic caused by searching for parking spaces | 0.04 | 4 | 0.16 |
| S16 | - Reducing fuel consumption and consequently reducing environmental pollution | 0.04 | 4 | 0.16 |

Table 7. Internal factors analysis from the perspective of experts

| Row | Strengths and weaknesses | Coefficient | Score | Final score |
|---|---|---|---|---|
| S17 | - Reducing the cost of air conditioning for covered parking lots | 0.02 | 3 | 0.06 |
| S18 | - Facilitating the search of a parked car | 0.03 | 4 | 0.12 |
| S19 | - Ability to create a blacklist and no-entrance permission for some cars along with software alarms | 0.03 | 3 | 0.09 |
| S20 | - Using artificial intelligence to identify high-emission vehicles and reporting and managing their traffic in the city. | 0.03 | 3 | 0.09 |
| S21 | - Ability to match the photo by the operator when entering and leaving to prevent theft and misuse | 0.03 | 3 | 0.09 |
| S22 | - Possibility to use your parking system without computer | 0.03 | 3 | 0.09 |
| S23 | - Online communication and network operation | 0.03 | 3 | 0.09 |
| W1 | - Weakened knowledge about the capabilities of the smart city | 0.04 | 2 | 0.08 |
| W2 | - Lack of specialist knowledge about smartization of parking lots | 0.02 | 2 | 0.04 |
| W3 | - The high cost of smartization infrastructures | 0.04 | 2 | 0.08 |
| W4 | - Lack of smartization infrastructures | 0.02 | 2 | 0.02 |
| W5 | - Weaknesses in the use of the private sector and their capabilities | 0.03 | 2 | 0.03 |
| W6 | - The lack of smart parking software | 0.03 | 2 | 0.03 |
| W7 | - The simplicity of existing software and their weakness in attracting users | 0.02 | 1 | 0.02 |
| W8 | - The prevalence of sensor-based parking and the possibility of error and misdiagnosis and misleading information to users. | 0.04 | 1 | 0.04 |
| W9 | - Low sensitivity and low resistance of sensors to weather conditions and poor performance in these cases where traffic may be even higher (rainy, snowy, or very hot weather) | 0.03 | 2 | 0.03 |
| W10 | - The high cost of using some of the sensors and networks, including the imaging camera in smart parking management | 0.03 | 2 | 0.04 |
| Total | | 1=100% | | 2.98 |

In the table on external factors, the results of the survey by experts suggest that the greatest opportunity that has affected the focus of smart parking lots is the formation of a smart city paradigm and an increase in attention to the Internet of objects, both of which are scored 0.24. In addition to these, the most important threat to smart parking lots which has minimized the amount of attention is the theoretical and scientific vacancy of this issue, the high costs of building smart parking lots and security threats, especially in smart parking lots equipped with cameras, which has earned a score of 0.16 by experts.

Meanwhile, by looking at Table 7 and based on the results of the interview and extracting the information from the questionnaire, the score obtained from the internal factor assessment matrix is 2.98 and since it is larger than 2.5 for external factors, it can be concluded that the strengths of smart parking are overcoming its weaknesses. Also, as shown in Table 8, the score obtained from the external factors assessment matrix is equal to 3.14, and since this number is greater than 2.5, it indicates that the opportunities available for use and reinforcement of smart parking approach and smart parking management overcomes the threats.

Table 8. External factors analysis from the perspective of experts

| Row | Opportunities and threats | Coefficient | Score | Final score |
|---|---|---|---|---|
| O1 | - The formation of the new paradigm of the smart city in the world and the need to pay attention to it in Iran | 0.06 | 4 | 0.24 |
| O2 | - The formation of smart cities organizations | 0.05 | 4 | 0.20 |
| O3 | - Formation of a part of the infrastructure necessary for smart city | 0.05 | 4 | 0.20 |
| O4 | - Artificial intelligence growth in cities | 0.05 | 4 | 0.20 |
| O5 | - Attention to the smart public transport approach in cities | 0.06 | 4 | 0.24 |
| O6 | - Increasing the use of smartphones by people | 0.04 | 4 | 0.16 |
| O7 | - Internet availability at city level | 0.05 | 4 | 0.20 |
| O8 | - Increasing people's knowledge about online services | 0.06 | 4 | 0.24 |
| O9 | - Considering the smart public transport approach in cities | 0.04 | 4 | 0.16 |
| O10 | - The possibility of online communication through urban software and applications in different areas | 0.04 | 4 | 0.16 |
| O11 | - The lucrative nature of this technology and the presence of investors from private sector to invest in this area | 0.03 | 4 | 0.16 |
| O12 | - Increasing the use of smart applications | 0.04 | 4 | 0.16 |
| T1 | - Theoretical and scientific vacancy related to the issue of smart parking (especially in Iran) | 0.05 | 2 | 0.10 |
| T2 | - The lack of support or minimal support for creative ideas of this field | 0.03 | 1 | 0.03 |
| T3 | - Lack of specialized staff in the field of smartization | 0.04 | 2 | 0.08 |
| T4 | - lack of variety of software available at the community level and the weakness of the software for smart parking | 0.03 | 1 | 0.03 |
| T5 | - Lack of necessary knowledge on the use of minimal software available (concerning parking lots) | 0.04 | 1 | 0.04 |
| T6 | - The citizens' ignorance of how to use the apps | 0.04 | 2 | 0.08 |
| T7 | - The lengthy process of designing and training how to use smart parking system applications | 0.03 | 2 | 0.06 |
| T8 | - The weak urban infrastructure needed to use some smart parking management systems | 0.05 | 2 | 0.10 |
| T9 | - High cost of smartization | 0.05 | 2 | 0.10 |
| T10 | - The possibility of abuse of spatial and temporal information of real and legal persons by installing sensors or smart cameras (security threats) | 0.05 | 2 | 0.10 |
| **Total** | | **1=100%** | | **3.14** |

***Matrix of internal and external factors***

The matrix of strategies and executive priorities places different parts of the system in a graph in four separate sections (Fig. 2). Pre and post-matrix studies provide such possibilities that expected strategic effects are predicted on the system. The matrix of strategies and implementation priorities is based on the deployment of data in two main dimensions: 1. The total score of the internal factor assessment matrix shown on the X-axis. 2. Total score of the external factors assessment matrix shown on the Y axis. In the matrix of strategies and executive priorities, these scores are classified in a strong two-part spectrum (2.5 to 4) and weak (2.5 to 1). In this matrix, if the location of the study area in terms of scores of external and internal factors is in the first part of the graph, if the offensive strategy is in the second part, the competitive strategy in the third part, and finally if the conservative strategy is in the fourth part, the defensive strategy is suggested.

In Fig. 1, the strategic location of a region is determined using the matrix of internal and external factors and the establishment of internal and external factors assessment matrices on it. As the total score of the internal factors on the X axis is 2.98 and the total score obtained from the external factors on the Y axis is 3.14; therefore, according to the principles of strategic management, the strategic position of the research is determined in area 1 of the graph, and consequently the offensive strategies (SO) will be selected. Accordingly, the necessity of paying attention to smart parking lots should be placed on the priority list of urban management and it is necessary to avoid passive approaches about this issue and to enter the field in order to benefit citizens by developing these types of parking lots.

***Presenting strategies based on the SWOT model***

This model is one of the most important tools in the process of compilation of the strategy by which the information is compared. Also, using this matrix, it is possible to formulate four choices with different strategies in terms of different degrees of activity in space; however, in practice, some strategies overlap or coexist with each other simultaneously. According to the results of the SWOT analysis, in order to understand the importance of smart parking and improve the urban management efficiency in utilizing these types of parking lots, the following strategies have been developed and presented.

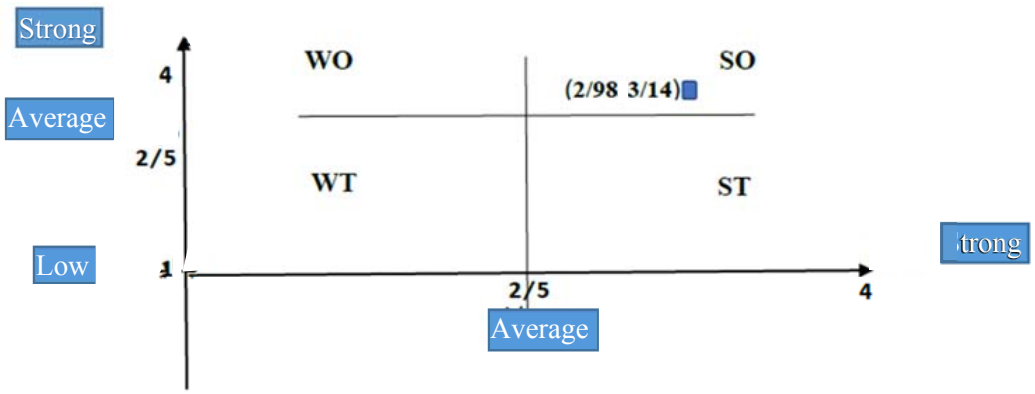


Fig. 2. Final score of internal factors assessment

Table 9. Urban management (SO, ST) strategies for optimal use of smart parking

| SWOT | Opportunities | Threats |
|---|---|---|
| | Strategies (SO) | Strategies (ST) |
| **Strengths** | Attempt to attract domestic and foreign investors to invest in Smart Parking | Increasing the safety factor of using sensors or smart cameras to reduce the misuse of time and location information of real and legal persons. |
| | Strengthening artificial intelligence infrastructure to increase control and reduce the level of human error in smart parking management | Focus on smart parking and smart infrastructure networks to reduce costs and increase productivity |
| | Reducing urban traffic by relying on the expansion of smart urban transportation systems and smart parking | Increasing awareness and knowledge of citizens through designing applications in the form of smart parking system applications |
| | Expanding and strengthening the online communication infrastructure to facilitate the use of smart parking software and applications. | Strengthening the knowledge of employees, brokers and users in the field of urban smartization and in particular the use of smart parking software and systems. |
| | Reducing the time of search for parking for drivers by informing parking capacity through the use of smart parking management software and applications. | Designing smart parking management software and applications with maximum detection efficiency and minimum cost and error. |
| | Using artificial intelligence in urban infrastructure, and in particular smart parking, to design reporting systems for identifying high-emission vehicles and their smart parking ban | Using affordable hardware and software, efficient and consistent with the native features of the city |
| | Facilitating the search of parked cars by relying on and strengthening smart urban applications connected to an integrated network and online communication. | Training active forces in the area of smartization to strengthen the human infrastructure associated with smart parking |
| | Enhancing the efficiency of management in the internal traffic flow by strengthening and investing in smart parking infrastructure | Supporting ideas for smart parking in order to achieve the best and most comprehensive solution |
| | Improving urban management by strengthening the smart parking approach due to the expanded use of the Internet of objects | Use and adaptation of global knowledge in the area of parking smartization and its localization according to the existing conditions |
| | | Focusing on the strategic and essential infrastructure of parking smartization to reduce unnecessary costs and increase sustainable municipality revenue. |
| | | Focus on new knowledge-based job opportunities in order to acquire the necessary knowledge in the design, implementation and management of smart parking |

Table 10. Urban management (WO, WT) strategies for optimal use of smart parking

| SWOT | Opportunities | Threats |
|---|---|---|
| | Strategies (WO) | Strategies (WT) |
| **Weaknesses** | Hardware and software risk management related to smart parking to reduce security threats | Strengthening training and study approaches to obtain the knowledge of city smartization and smart parking |
| | Strengthening smart parking infrastructure by relying on the global smart city approach and expanding smartization organizations | Equipping managers and citizens with parking smartization to facilitate and efficiently use and manage smart parking |
| | Training how to use smart parking apps with the spread of smartphone usage, online communication and Internet access at the city level | Investing in the vital infrastructure of smart parking to prevent unnecessary costs |
| | Negotiating with the private sector to support ideas for smart parking because of its high profitability | An attempt to attract the private sector in setting up smart parking lots considering its high profitability |
| | | Designing accurate and powerful software in the management and use of smart parking |

## Conclusion

Parking is one of the three main urban transportation elements. Most light and heavy vehicles should stop at the end of every trip at some location; even in areas where public transportation is serviced, personal vehicles are preferred, and therefore, parking space is an ever increasing need. The need to pay attention to parking in the present time is increasingly expanding. In fact, the increase in vehicles, the physical-spatial expansion of cities and the lack of easy access to various parts of the city have increased the use of personal vehicles. However, the central part of most metropolitan areas, which have both higher population density and wide range of applications, do not have the capacity to accommodate many cars, causing heavy traffic and an increase in pollution levels in these areas. Because most people flock to these areas, not caring about parking space; this is while parking spaces are already crowded and the people are not aware of the situation and they are trying to find a place to park unaware of the fact that this is one of the most important factors affecting urban traffic and pollution in these areas.

Urban management, with no regard to the importance of parking and its purposeful management, has left this issue passively and has provided the platform of disturbances in the densely populated areas of the city. In recent years, with the arrival of the smart city paradigm, the opportunity of smart management of these spaces has become more and more possible. Unfortunately, this paradigm is still marginal in Iran for many reasons,

perhaps one of the most important of which is the theoretical vacancy and the lack of specialists in this area. While one of the main components of a smart city is smart transportation which addresses a variety of issues such as smart parking lots. The identity of these parking lots are based on information and communication technology, artificial intelligence, the internet of things, and ultimately smart citizens, providing smart parking management for cars.

However, the lack of knowledge in this regard has lowered the level of attention to these parking lots. Therefore, in this research, by considering the ideas of experts from in the field of transportation and urban management, internal and external factors affecting smart parking lots has been addressed. Further, strategies have been developed and presented to increase the efficiency of these types of parking lots and to understand the necessity of them.

Twenty strengths, 10 weaknesses, 12 opportunities and 11 threats were extracted from the interviews conducted with the experts. After analyzing the data and conducting evaluations, the most important strengths of smart parking lots were identified to be "increasing municipalities revenue", "reducing part of traffic in the city", "reducing search times for parking space" and "reducing petrol consumption and reducing pollution", all of which received a score of 0.16. However, the most important weaknesses in these parking lots were proved to be "lack of knowledge and understanding about the capabilities of smart parking lots", "high costs of infrastructure " and "lack of trust of organizations to the private sector to invest on this field", all of which scored 0.08. However, the highest opportunities that have affected the focus of smart parking lots include "smart city paradigm development," "increasing the attention to the internet of things," and "increasing smart citizens" all of which had a final score of 0.24. In addition, the most important threats to smart parking which have also minimized their attraction were "theoretical and scientific vacancy regarding this issue," "the cost of building smart parking lots" and "security threats, especially in smart parking lots equipped with camera" which have obtained a score of 0.16 by the experts.

Finally, using the SWOT model analysis and assessment matrix, some strategies were developed to overcome the weaknesses and neutralize the threats of smart parking lots that urban managers can use to take measures to efficiently manage smart parking spaces and reduce environmental pollution and thereby increase citizens' satisfaction and efficiency.

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