An Intelligent Parking Management System using RFID Technology based on User Preferences

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Abstract Due to the tremendous progress in the automotive industry, the growth of the urban population, the number of vehicles is increasing and this creates parking challenges. Intelligent parking management systems offer an optimal solution for finding empty parking space so that drivers can quickly find their car parking space. To solve these problems, it is necessary to design an intelligent parking system, in addition to providing comfort to drivers, which is also economically viable. This paper proposes an intelligent multi-storey car parking system with the help of RFID technology and examining user preferences that can effectively solve car parking problems. The proposed method is a multi-objective decision-making method to reduce the problem of car parking, which is called MODM-RPCP. Therefore, the proposed MODM-RPCP method can allocate the best space for their stopping place by using the decision-making system and based on the priorities considered by the users. The simulation results show that the MODM-RPCP reduces the average booking time more than 19.2% and 27.1%, and decreases the response time of central parking management server more than 20.1% and 29.78% compared to MOGWOLA and ODPP approaches.

Keywords Parking Management System . Smart parking . Multi-objective method . Decision-making method

1 Introduction

Due to the increasing number of vehicles, traffic congestion is a worrying problem around the world and it is increasing day by day. Almost every day, about 40% of car traffic congestion in all countries of the world is due to the search for car parking space, and it takes an average of 10 to 12 minutes for

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the driver to find the parking space for the car. Such issues lead to traffic congestion, leading to increased waiting times for drivers and wasted car energy due to parking searches. The car parking problem needs an optimal solution to save driver time, reduce pollution and economic losses [1, 2].

Smart parking systems can be solved with the help of innovative solutions, by integrating different resources to upgrade facilities and parking management. These parking systems can provide real-time updates to users about the nearest available parking spaces. It can also provide a smart parking management system for booking and checking empty spaces remotely. These parking systems consist of low-cost sensors, real-time data collection and automated mobile payment systems for booking [3]. With RFID after intelligent parking identification, additional features such as fast car recovery, parking adjustment, parking gate management can also be used. Smart parking can be modelled as a parking gate. In each parking slot, a sensor is placed to detect the presence or absence of a vehicle that creates an access map to guide parking and other services. Such a system can also be considered as a problem of managing multiple parking lots because it has to manage multiple parking lots distributed in different internal and external areas. To design intelligent parking systems, the connection of the sensor measurement to a physical location is essential [4].

Instead of deploying all vehicles with GPS capability, it is preferable to have only a few vehicles on the network to identify their exact location via GPS. These vehicles are referred to as anchor or reference vehicles. Other network nodes will be able to show their position close to anchor nodes by measuring the received signal strength (RSS) and arrival time. These methods have made significant progress in computational accuracy and timing. Figure 1 shows the proposed method architecture where different drivers are communicating with the parking management server in order to determine the empty parking spaces.



Fig. 1 Multi-objective decision-making method to reduce the problem of car parking architecture

This study presents a smart multilevel parking management system using RFID and checking users' priorities, which can efficiently solve the parking problems. The proposed method called MODM-RPCP is a multi-objective decision-making method that reduces the parking problem.

The rest of the paper is organized as follows: Section 2 presents related works. In Sect. 3 brings the proposed MODM-RPCP solution. The parameters used for assessing the performance are studied and

simulation outcomes are deliberated in Section 4. Finally, conclusion of this research is discussed in Section 5.

2 Related works

Cyprus International Airport decided to use the Hikvision smart parking system to minimize the problems caused by parking cars and protecting them. They left the access control system, the smart airport parking system, and also monitoring other parts of the airport to the closed-circuit camera system of Hikvision. In this solution of Hikvision, the barriers installed in the car park entrance are controlled smartly using sensors and special radar. Efficiency of this model has other advantages in addition to easy installation and setup which include not being affected by environmental factors like lighting, dust, and rain. In addition to the automatic and smart barrier control capability, this system can leave some of the control manually to the operator. By using smart algorithms and modern technologies in the security and closed-circuit field, the Hikvision smart system can present valuable statistical and analytical information to the managers so that, if necessary, they can make important decisions using this information and increase security and customer satisfaction levels [5].

In some studies that Zung et al. conducted for understanding the decisions in car parks by modeling the structural equation, they have created a structural equation for analyzing parking decisions. The data used in this study was obtained from Information Park in Beijing. The relationships between the three parking decisions were studied. The results show a two-way correlation between street park and duration. These findings can be used for developing some measures for regulating interact Analysis of parking in the car park and the parking mechanism for balancing parking time-time distribution and also formulating parking management policies [6].

Maravel et al. have solved the problem of automatic parking using a rear-wheel drive vehicle using a biometric model based on the direct connection between the perception of the vehicle and actions. This problem has been inspired using the external approach where the vehicle controller does not need to know the car communique and dynamics. Also, it does not require previous knowledge of the environment's map. The main point in the proposed approach is the definition of performance indicators that happen to automatic parking and actions are injected to the car robot controller in real time. This solution is in the form of a multi-objective dynamic optimization problem and is extremely analytical. Using the genetic algorithm, they have obtained a very simple and effective solution [7].

In the studies Zhao et al. have conducted on analyzing the activity-based trip chain in the parking fee network program, they incorporated the chaining behavior of activity-based trip in analyzing network stability and an integrated model has been presented for describing the passenger's behavior, which is a combination of Beckman link congestion terms and type two logit demand function. The convexity conditions and equivalence of the model have been discussed. Based on the integrated model, a two-layer model has been designed for maximizing social welfare through suitable parking cost. Also, an extensive network for eliminating services and trips in the main network has been developed. Then, the Simulated annealing (SA) method has been used for solving the proposed two-layer model. Numerical examples have been presented for studying the availability of the model and the effects of parking fee scheme on passengers' behavior and social welfare, which indicate that this model is effective in describing the trip chaining behavior in the network [8].

To solve the traffic pressure caused by container trucks in ports, Chang et al. proposed an underground container logistics service (UCLS) between Shanghai terminal and north west of logistics park. To ensure the connection between the system and the terminal, designing an underground parking is proposed. Underground parking is a buffer that is used for loading and unloading underground vehicles (UGVs). A nonlinear ordinary planning model (MNIP) has been designed for UGVs and outdoor cranes in order to minimize the overall cost of the cranes in line for UGVs and terminals. Then, the optimization model has been implemented using MATLAB software [9].

Oren Steen et al. have designed a parking management system that comprises a central dataset in communication with the server, at least one user device, at least one merchant console, and one parking control device in a network. The central database is presented for receiving and storing data from several parking systems. A process has been presented for analyzing the information received by the central data base. A dynamic data engine has been presented for analyzing the data received from a number of parking systems and generating dynamic data. Targeted advertising engine has been presented for analyzing user's data and creating a targeted advertisement. Dynamic pricing information are given to user's device so that the user can reserve the parking space from one of the parking systems. Targeted promotion is given to user's device so that the user can choose an advertisement from a merchant [10].

Works carried out in Iran related to smart car parks:

a) designing a smart parking management and guidance system and its role in securing and increasing road capacity according to paper [11]. To obtain information, first they have referred to the reality of the society and through interviews, questionnaires, and case studies addressed the issues and problems present regarding car parks. This paper is conducted using the descriptive method and on 70 citizens (driver). In the following, we address some of these questions and tables.

According to Table 1, the results of this study regarding the satisfaction level of drivers from parking services around the city were at the low and medium level and only 6 percent have high satisfaction.

-							
	Low	Medium	High	Overall			
	27	39	4	70			
	38%	56%	6%	100%			

 Table 1 Satisfaction level with services [7].

According to Table 2, it shows that locating a parking location by asking the people of the region is the highest at 48 percent. Drivers trying to find a parking spot on the street is second with 30 percent and routing systems with 3 percent has had the lowest usage by drivers.

OF FL					
Asking people of the region	Using	Using traffic	Using city	None, try to find a	Overall
	locators	signs	map	spot on the street	
34	2	9	4	21	70
48%	3%	13%	6%	30%	100%

Table 2 Results of asking people [7].

According to the results of Table 3, this question has been raised that how important the factors affecting a parking spot are and therefore, the drivers were asked to score the factors mentioned in the questionnaire according to their effect on choosing a parking spot from one to ten. These results show that some parameters affecting parking selection play a more important role while other factors are less important.

Parameter effective in ranking	Importance weight	
Access time to parking	0.42	
Geographic distance	0.45	
Parking fee	0.51	
Security and safety	0.32	
Parking difficulty	0.12	
Predicting the future regarding vehicle exit	0.24	

 Table 3 Importance weight of different factors effective in ranking

And in the final question where drivers were asked about highest services to the customers, they ranked mentioned factors from one to four and the results are presented in Table 4. which shows the importance of providing better parking services with regard to market work with the highest share at 38 percent.

Table 4 Maximum services provided to the customers by car parks

Parameter	Importance weight	
During office hours	0.38	
With respect to market work	0.32	
With respect to recreational, cultural, and tourism centers	0.17	
During Norouz, eves, religious festivals, and holidays	0.14	

Works carried out abroad related to smart car parks:

a) Parking Guidance and Information System (PGIS): As a part of smart transportation systems, it can be useful for solving traffic problems. The state of traffic in big city areas has become severe due to looking for parking spots. Advanced parking guidance and information system is considered one of the most effective traffic management approaches which can control and effect the usage of vehicles, especially in crowded and busy parts of the city. Beijing was chosen to host the 2008 Olympics and the government of China has acknowledged that these games would be the most splendid in Olympics history. Before holding these games, it was evaluated in an overall analysis that one of the factors that would affect Olympic games was the traffic system and Beijing officials decided to provide a comfortable, safe, and accurate traffic system to reduce the negative effects of this matter on Olympic games. Despite the fact that nowadays many traffic indicators of china like road network congestion, number of licensed cars, and number of daily passengers are at the top of global rankings, infrastructure facilities of Beijing are behind the global trend with regards to traffic management [11].

Traffic properties of Olympics are defined as follows:

- Short-term events
- High congestion
- High demand

One of the tools used by Beijing officials in managing Olympics traffic was controlling and scheduling the traffic in Olympics village. From 1997, Chinese Academy of Sciences has started two massive projects in order to research and develop regarding traffic issues. The initial name of this project was "Urban Traffic Flow Guidance System". Jilin University was responsible for carrying out one of these

projects. Due to this reason, a research group was formed to design and build a system for the information and management of car parks. This system was named "Urban Traffic Flow Guidance System" [12]. The scheme for integrating parking guidance with traffic flow guidance in smart transportation systems is shown in Figure 2.



Fig. 2 The scheme for integrating parking guidance with traffic flow guidance in smart transportation systems [12].



Comparison of targeted car parking is shown in Figure 3.

Fig. 3 Comparison of targeted car parking duration before and after utilizing the PGIS system in on of Beijing's regions [12].

b) Smart Driver Location System for Smart Parking: Often, finding a parking spot is tiresome for the drivers and the car park itself is expensive in all the major cities of the world. In [13], a crowdsourced

solution has been proposed that gathers the real information of available car parks using the sensors in smartphones. This system is designed based on cell phones which can follow the driver's route until he or she wants to leave the car park. In this paper, it has been focused on the efficiency and accuracy of using mobile phones for depicting the driver's walking route, which is carried out using the pedestrian dead reckoning (PDR) method installed on the belly and can measure the driver's moving distance with high accuracy. Also, an algorithm synchronous with the map has been designed to measure route errors while the driver is indoors (interior environment). It has carried out this deed by utilizing existing floor maps of buildings. The results have shown that it can guess user's walking distance with an approximate accuracy of 98 percent, which along with location errors is about 0.48 meters. In this paper, it has been focused on how to detect the exiting car park activity. This idea is very simple because if the phone detects that the driver is approaching where his or her car is parked, it seems like the driver wants to leave the spot and the parking spot will be available soon.

In [13], a driver, who has parked recently, can provide a message regarding when he or she wants to leave the spot and this information might be sold to another driver who wants to pay (using virtual money, like Bitcoin). Once the buyer reaches the parking spot when it is close to the departure time of the seller, he can occupy the spot after the seller leaves. Therefore, drivers only exchange the information regarding available car parks. This action is carried out automatically in this paper, i.e. the act of registering and removing parking spots is done automatically. The main focus of this paper is on how the walking path of the driver, which is the key to this method, can be efficiently and accurately depicted. According to this paper [13] and all their previous research, previous systems all worked manually and could not automatically carry out the park registration and removal operation and so the users needed to apply this operation manually. In order for his system to be able to carry out this operation automatically, it needs to monitor user's behaviour.

In [14] the authors proposed a method that uses a machine learning method to predict parking occupancy, which in turn is used to deduce occupied driving prices for the entry of vehicles. Parking data on Seattle City Street has been used to train, test and compare different models of machine learning. This is the first time a parking occupancy forecasting system has been used to generate an occupancy-based parking price for a Seattle street parking system.

In [16], the authors proposed a multifunctional gray wolf optimization technique with the aim of minimizing the localization error. For telemetry and geometric constraints, two objective functions are considered. In our research for the optimal localization of wireless sensor nodes with IoT capability to determine their positions in smart parking with the aim of developing a model based on the optimization of multifunctional gray wolf. Objective functions include distance and topological constraints. Using the multi-purpose gray wolf optimization (MOGWO), the Pareto optimal solution is obtained to determine the optimal solution. The goal of localization is to achieve efficiency and reduce the number of anchor nodes.

3 The proposed MODM-RPCP solution

As the number of cars increases, finding a parking space becomes a challenge. The drivers usually do not know if there is a space for them to park their car or not. Also, finding a proper space in the large multilevel parking facilities for users, especially those who park for a short time, is difficult and a waste of time. Therefore, the parking issue has become one of the main issues in urban transportation management, because the urban spatial resources are limited and parking cost is high. Due to limited parking space, many vehicles spent much time in the streets to find a proper parking slot, and wait in

long queues to park or retrieve their car. Smart multilevel parking facilities are constructed at the center of most large cities to handle these limitations and develop an intelligent approach to inform the drivers to select parking facilities. This study presents a smart multilevel parking management system using RFID and checking users' priorities, which can efficiently solve the parking problems. The proposed method called MODM-RPCP is a multi-objective decision-making method that reduces the parking problem.

3.1 The General Architecture of the MODM-RPCP

A short-range wireless communication technology capable of detecting radio frequency is called RFID technology, which can read or write related data via radio signals without any mechanical or optical communication. It also has the ability to identify specific targets. The proposed MODM-RPCP method introduces a multilevel parking space management method based on priorities, including parking management, and reducing search time. The management system of the parking space information also implements the parking guide management and parking costs in each parking. This system manages parking space using RFID tags and parking search time reduction criteria called CRPST.

The proposed MODM-RPCP method comprises the following sections: decision-making, input control, and output control. The multilevel parking space management structure is shown in Figure 4.



Fig. 4 The general architecture of the multilevel parking space management

3.2 Phase 1: Decision-Making

In this phase, a model is introduced for optimal allocation of the vehicles to the spaces existing in the intelligent multilevel parking aiming to reduce the waiting time, cost, and energy loss. Some symbols are used in this section, which are described in the following.

These symbols include the input cars, parking floors, parking locations on each floor, as shown in Table 5.

Symbol	Description
I_M, I_M	$\{1, 2, 3,, I_M\}$ Input cars
P_F, P_F	$\{1,2,3,\ldots P_F\}$ Parking floors
F_L, F_L	$\{1,2,3,\ldots,F_L\}$ Parking locations at each floor

3.2.1 Introducing the Parameters

The parameters of the proposed method include time interval, duration (how long a car parks), and time to space index, as given in Table 6.

Parameter	Description		
T_{F_L/P_F}	Time interval of F _L at P _F		
ST_V	The time that the vehicle V parks at the parking.		
A_{V}	The space required to park the vehicle V.		
$CRPST_V$	Park hours of each vehicle per unit space of vehicle V.		

Decision-making, including definitions like allocating a vehicle to a parking floor, and selecting a parking space in the corresponding floor is introduced as in Table 7.

Table 7 Decision-making variables

Variable	Description
$lpha_{_{V/P_F}}$	1, if the vehicle V is allocated to PF.
	0 otherwise.
$eta_{_{F_L/P_F}}$	1, if FL is allocated to PF.
	0 otherwise.

3.2.2 Decision model for allocating a vehicle to the parking

The decision-making model for allocating a vehicle to parking spaces is a nonlinear objective (cost) function, including integer variables aiming to reduce the total time of allocating the vehicles to the specified parking slot. This function comprises elements like the total number of allocated vehicles, and the time interval of the allocated parking slot from the entrance/exit.

$$Minx = 2*\sum_{P_F} \left[\left\{ \frac{\sum_{F_L} \left(T_{F_L/P_F} * \beta_{F_L/P_F} \right)}{\sum_{F_L} \beta_{F_L/P_F}} \right\} * \left(\sum_{I_M} \alpha_{V/P_F} \right) \right]$$
(1)

$$CRPST_{V\alpha_{V/P_{F}}} \leq CRPST_{V'\alpha_{V'P_{F}}} \qquad \forall V \neq V' , P_{F} \neq P_{F'}$$

$$\tag{2}$$

$$F_{L} * \beta_{F_{L}/P_{F}} \leq F_{L} * \beta_{F_{L}/P_{F}} \qquad \forall F_{L} \neq F_{L} , P_{F} \neq P_{F}$$
(3)

$$\sum_{P_F} \alpha_{V/P_F} = 1 \quad \forall V \tag{4}$$

$$\sum_{P_F} \beta_{F_L/P_F} \le 1 \quad \forall F_L \tag{5}$$

$$\sum_{V} \left(\alpha_{V/P_{F}} \right) \leq \sum_{F_{L}} \left(\beta_{F_{L}/P_{F}} \right) \qquad \forall P_{F}$$
(6)

$$\beta_{F_L/P_F} \in \{0,1\} \qquad \forall F_L, P_F \tag{7}$$

$$\alpha_{V/P_F} \in \{0,1\} \qquad \forall V, P_F \tag{8}$$

In the proposed model, constraints (2) and (3) are considered to ensure that a vehicle allocated to floor P_F and location F_L has a smaller CRPST than the vehicles allocated to floor P'_F and F'_L . Because floor P_F and location F_L are closer to the entrance/exit compared to P'_F and F'_L . Since one vehicle can be allocated to only one location in one parking level, the constraint (4) is used. On the other hand, constraint (5) represents that a parking location F_L can be allocated to one parking floor. Finally, the vehicles on floor P_F and location F_L should be balanced as represented in constraint (6). The constraints (7) and (8) apply the dual (binary) constraints to the decision variables. As seen in the model, in the first constraint, the vehicle with smaller CRPST is allocated to a lower level. This criterion that is represented by constraint (9) is obtained through dividing the time that the vehicle V parks at the parking by the space required to park the vehicle V. In this equation, ST_V is the time that the vehicle V stops at the parking and RS_V is the space required to park the vehicle V.

$$CRPST_V = \frac{ST_V}{RS_V} \tag{9}$$

According to Eq. (9), if the duration demand of the vehicle is reduced, its CRPST is decreased, and the vehicle with shorter requested duration at the parking has a higher priority for parking in floors and locations closer to the exit/entrance.

3.3 Phase 2: Entrance to the Parking using MODM-RPCP

In the proposed MODM-RPCP method, the general schematic of the parking is shown in Figure 5.



Fig. 5 Entrance to the parking

The hardware employed in the input control includes antenna, tag reader, automatic card issuance, automatic rail, decision-making terminal, and positioning, which is aware of the vacant space of each parking facility.

The RFID tag reader includes an antenna, tags, and readers. The reader device reads the label information, which contains a unique number, when the label enters the cover of the electromagnetic wave emitted by the antenna. Then, using the decision-making terminal and based on the previous discussion, the location and floors of the parking, which is a serial number similar to the tag is allocated to the input vehicle. First, the input vehicles receive an entrance card via the automatic card issuance device, if all parking slots are full, the device does not issue any card and announces that the parking is full; if there are vacant spaces in the parking, the vehicle enters. Each specific vehicle receives an RFID tag from the card issuance device, which includes information of the vehicle, personal information of the driver, including account number and duration. Then, the parking information stored in the database is examined, and a vacant space in correspondence with the individual's request is allocated to the vehicle.

A vehicle is controlled via RFID when it enters the coverage area of the EM waves emitted by the antenna. If the tag is valid, and a space is allocated to the vehicle, the input rail goes up, and the vehicle enters the parking without stops to reach the allocated location; if the tag is invalid, the rail does not go up.

As mentioned in the decision-making section, if the user wants to park for a shorter time, it is allocated to a closer space in the lower levels using the decision-making system. When the vehicle enters, its entrance time is automatically recorded in the database, then the rail goes up automatically to let the vehicle in, and when the vehicle enters the rail goes down.

Since the parking is multilevel and has many spaces, after allocating a space to a user, the user should be directed to find the space faster. In this method, the public guidance used in the conventional parking management cannot be used. Therefore, in the proposed method, a fast positioning system with a user display system is used. This system helps the user find its parking space fast. This system is comprised of the previous hardware facilities, including control, reader, RFID tags, antenna.

The parking floors are plotted on the planar electronic map; the users can use this map to find the parking space easily. When the user reaches the parking space of interest, enters its parking card received automatically at the entrance to the installed terminal. Then, the user carries the tag with himself/herself to find the parking space considering the terminal reminder. The positioning system of the multilevel parking is shown in Figure 6.



Fig. 6 Positioning and parking space representation

As shown in Figure 6, each parking space on each floor is represented by a unique ID. The bold cells represent the occupied spaces, the empty cells represent the empty spaces, and the parking space of interest is represented in green, which blinks. The graphical electronic map shown in Figure 6 is relatively simple, and it is only used as an example. In real conditions, the map is 2D and plotted based on the parking space distribution. The parking positioning system and the representation terminal are installed at the entrance of all parking facilities; only some spaces are shown in the figure. This terminal simplifies finding the parking space and making queries. The process performed at the entrance and finding the allocated parking space is shown in Figure 7.

3.4 Phase 3: Fast Exit from the Parking in MODM-RPCP Method

As fast entrance to the parking is important and reduces waste of time, fast exit from the parking also plays an essential role in reducing waste of time. The required devices for exit control are as follows:

A common computer with the entrance system and control database, card reader and antenna, card restoration device, automatic rail, parking cost display based on duration, and the paid bill printer.



Fig. 7 Parking entrance flowchart, allocating space by the decision-making system and finding the allocated space

Since the parking space is very large and the parking spaces are similar, the users might forget their parking space. However, they can use the parking card and the electronic map terminal to find the information about the parking space. When a user enters the area covered by the EM waves, the system automatically reads and records the parking card information. After finding the vehicle, when the user leaves the parking, the parking card should be returned to the card restoration device. Then, the system automatically reads the card information, records the duration, and calculates the costs, and the costs

are deposited from the users' account using RFID tags when exiting the parking. After paying the bill, the rail goes up automatically, and the user exits. The flowchart of fast exit control is shown in Figure 8.



Fig. 8 Flowchart of exit from the parking

4 Evaluating the Performance

This section evaluates the qualitative performance in the form of numerical results to validate the performance of the proposed MODM-RPCP method. To demonstrate a feasibility study, the performance analysis of MODM-RPCP has been divided into two parts:

- 1) Average booking time,
- 2) Response time of central parking management server

4.1 Performance metrics

The proposed MODM-RPCP method has been simulated and its performance evaluated in Network Simulator version 2 (NS-3) running on Linux Ubuntu 18.04 LTS. The results were compared with both methods (ODPP [14] and MOGWOLA [16-25]).

4.2 Simulation results

All three methods are evaluated according to Table 9 under three scenarios. Table 9 displays the significant parameters used in the simulation. In this section, the performance of our proposed approach is evaluated using NS-3 on Linux Ubuntu 18.04 LTS as the simulation tool, and the results are discussed further. Table 8 displays the significant parameters used in the simulation [26-32].

 Table 8 Parameters used.

Parameters	Value
Operating System	Linux Ubuntu
Topology	200m X 200m
Number of vehicles	200
Days	Saturday, Sunday, and Monday
Maximum iterations	10
Technology	RFID
Transmission range	30, 40, 50, and 60
MAC Protocol	802.11p
Simulation time	1000 second
Packet size	64 bytes

Table 9 Parameters used for four scenarios.

Scenario #1		Scenario #2		
Day	Saturday	Day	Sunday	
Topology	300m X 300m	Topology	300m X 300m	
Time	1000	Time	1000	
Scenario #3				
Day	Monday			
Topology	300m X 300m			
Time	1000			

Table 10-15 compares the performance of MODM-RPCP solution vs ODPP and MOGWOLA methods in terms of average booking time, and response time [33-38].

Table 10Average booking timeTime of Day(Saturday) vs Time of Day

	ODPP	MOGWOLA	MODM-RPCP
8:00	80	73	54
10:00	95	85	59
12:00	110	93	62
16:00	85	71	52
18:00	100	80	58
20:00	123	98	65
22:00	112	92	62

Average booking time (second)

Table 11Average booking timeTime of Day(Sunday) vs Time of Day

Time of Day	Average booking time (second)			
	ODPP	MOGWOLA	MODM-RPCP	
8:00	95	88	64	
10:00	110	100	79	
12:00	125	108	73	
16:00	100	86	64	
18:00	115	95	69	
20:00	138	113	78	
22:00	127	107	74	

Table 12 Average booking time(Monday) vs Time of Day

Average booking time (second)			
ODPP	MOGWOLA	MODM-RPCP	
90	82	59	
105	95	74	
120	102	68	
95	80	59	
110	90	64	
133	106	73	
120	101	69	
	Avera ODPP 90 105 120 95 110 133 120	ODPP MOGWOLA 90 82 105 95 120 102 95 80 110 90 133 106 120 101	

Table 13 Response time of central	Time of Day	ime of Day Average booking time (second)		ond)
parking management server (Saturday) vs Time of Day		ODPP	MOGWOLA	MODM-RPCP
	8:00	25	18	12
	10:00	31	23	14
	12:00	38	29	16
	16:00	31	24	10
	18:00	34	29	13
	20:00	36	35	15
	22:00	30	31	12

Table 14 Response time of central	Time of Day	Average booking time (second)		
parking management server (Sunday) vs Time of Day		ODPP	MOGWOLA	MODM-RPCP
	8:00	29	22	15
	10:00	35	27	17
	12:00	43	33	19
	16:00	36	27	14
	18:00	37	30	17
	20:00	39	31	18
	22:00	34	32	15

Table 15 Response time of central	Time of Day	Average booking time (second)		
parking management server (Monday) vs Time of Day		ODPP	MOGWOLA	MODM-RPCP
	8:00	24	17	10
	10:00	30	22	12
	12:00	35	28	14
	16:00	30	22	9
	18:00	33	25	12
	20:00	34	26	13
	22:00	29	27	12

Average booking time: Figure 9 shows the simulation results of average booking time in three days of the week for the proposed method, ODPP, and MOGWOLA. As shown, this metric is shorter for the proposed method than the two other methods in all three days. In the ODPP method, the machine learning-based methods are used to predict the parking occupancy, and the learning is carried out using the collected data, while the users might have different requests for which the machine is not learned. In MOGWOLA, the grey wolf optimization is used to reduce the computation error, and as a result, the node is localized and positioned faster. Thus, MOGWOLA outperforms ODPP. However, this method also does not consider the user requests and does not discriminate between the users with different durations (how long a user parks). In the proposed MODM-RPCP method, the system makes decisions based on the users' requests and its duration and allocates a proper parking space to the user. As shown in Figure 9, in all three days, at the first hours of the morning, the average booking time increases because the offices are open and the number of users that need a parking space increases, and it decreases at noon. Then, it increases again in the afternoon as the stores open and the requests increase. However, the critical point is that in all hours of the day for all three simulated days, the proposed method outperforms the other two methods and has a shorter average booking time. The main reason is that the decision-making system decides based on each user's information and its duration.



B: Sunday



Fig. 9 Average booking time vs Time of Day.

Response time of central parking management server: As shown in Figure 10, the server's response time in different hours of the day in three days of the week for MODM-RPCP is shorter than ODPP and MOGWOLA. Because in the proposed MODM-RPCP method, the decision-making system selects a parking for each user based on its requirement and duration, and the users with shorter duration are allocated to spaces close to the entrance/exit. On the other hand, in the proposed MODM-RPCP method, a positioning terminal is used in each parking, that the user can use it with the RFID tag on the card and the electronic map to find its parking slot fast. Also, in the proposed method, all payments are made automatically using the RFID tag that reduces the response time. As seen in Figure 10, from 9 to noon, the response time is increasing, because the offices are open and the requests for parking facilities is high; thus, the number of requests to servers is high. From 12 to 16, as the offices are closed, the response time decreases, and it increases again in the afternoon as the stores and markets open, and the requests increase. The response time decreases again at the end of the night when the requests decrease.

critical point is that in all hours of the day, the proposed method's response time is shorter than the two other methods because of employing the decision-making system.



Fig. 10 Response time of central parking management server vs Time of Day

Therefore, the proposed MODM-RPCP method can allocate the best parking space using the decisionmaking system and considering the users' priorities. Also, using the RFID technology with the decisionmaking system provides the possibility of fast entrance/exit to/from the multilevel parking without wasting time and reducing energy consumption.

5 Conclusion

This paper proposes a way to find empty space in the parking lot using RFID technology. In the first phase, the proposed MODM-RPCP method, using the decision-making system, and based on the preferences of users, allocated the best space for parking the car. Then, in the second phase, using RFID technology along with the decision-making system, it provides fast entry and exit from the large multi-storey car park without wasting time and reducing energy consumption. The proposed MODM-RPCP was effective in terms of parking space, according to the proposed optimal solution in all three different scenarios. In addition, the simulation results show that the MODM-RPCP improves the average booking time, and response time of

the central parking management server, significantly. The proposed method calculated the optimal solution in less time. It also ensured faster vehicle placement in the empty space and improved network performance.

Conflict of Interest

None.

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