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A Multiple-Criteria Algorithm for Smart Parking: Making fair and preferred parking reservations in Smart Cities

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ABSTRACT

Smart cities are struggling with using public space efficiently and decreasing pollution at the same time. For this governments have embraced smart parking initiatives, which should result in a high utilization of public space and minimization of the driving, in this way reducing the emissions of cars. Yet, simply opening data about the availability of public spaces results in more congestions as multiple cars might be heading for the same parking space. In this work, we propose a Multiple Criteria based Parking space Reservation (MCPR) algorithm, for reserving a space for a user to deal with parking space in a fair way. Users' requirements are the main driving factor for the algorithm and used as criteria in MCPR. To evaluate the algorithm, simulations for three set of user preferences were made. The simulation results show that the algorithm satisfied the users' request fairly for all the three preferences. The algorithm helps users automatically to find a parking space according to the users' requirements. The algorithm can be used in a smart parking system to search for a parking space on behalf of user and send parking space information to the user.

CCS CONCEPTS

• **Networks → Network services**; **Cloud computing**; • **Information systems → Decision support systems**; *Information systems applications*; *Expert systems*;

KEYWORDS

Smart city; smart parking; reservation algorithm; multiple-criteria decision analysis

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1 INTRODUCTION

Smart cities employ data to improve their planning [20]. Open data can be used as fuel for the creation of smart cities [9]. The ability to effectively and efficiently combine, link and share data will determine such data's value [10]. Often algorithms are needed to process the data [11]. Smart cities are a response to the challenges that cities face in meeting objectives regarding socio-economic development and quality of life [17]. The smart city concept has been defined in different ways [13], where definitions vary from smart urban space to environmentally healthy smart cities [5]. Smart cities refer to types of technology-supported innovation in urban spaces and city governments [18]. Smart city research captures a variety of approaches, models and domains [1].

Smart Parking is an important and integral part of smart city initiatives. Vehicle are facing huge problem for finding a proper parking space in the roads of major cities. It becomes even worse in the important/posh area of major metropolitan cities. This leads to wastage of valuable time of civilians as well as consumes more fuel resulting in pollution [15]. The flow of traffic is also hampered while roaming for finding a proper parking space near to the destination and it results in road congestion as well as environmental pollution. However, simply opening data is not feasible solution, as places might be already full when arriving and it is also impractical for all the citizens or drivers to exactly know the parking area to every destination. Specially, when they are going to visit hospital, theater, restaurant and so on and are under time pressure there is a need for giving priority to for example, disabled people who should go to hospital urgently.

Manual parking systems cannot guide the users in well-organized way to their desired parking destination, thus sometimes make the situation poorer. When the number of available spaces is limited in a particular area and the users, who have this information, might try to acquire that space at the same time. As a result, it causes severe congestion on road and delay to reach the destination and worsening the problem instead of improving it. The availability of such information might keep on searching for vacant spaces in the neighbouring parking area. This type of strategy is called *"blind search strategy"* [21].

In addition, parking information sharing mechanism is commonly used by the currently smart parking system [14]. It publishes the availability of the parking spaces and the user will decide on their

desired parking destination. Though, it will not solve the congestion problem at rush hours due to unavailability of the parking spaces. As a result, a large number of users are in demand for the same parking spaces resulting in severe congestion again. This phenomenon is called *"multiple-car-chasing-single-space"* [21].
Therefore traditional manual parking system can be replaced by automatic smart parking system to find proper parking location with ease. To reduce the traffic congestion, delay and harassment of users for parking their cars it is recommended that each user must reserve a parking space through smart parking management system. Such a system will decrease transaction costs [15]. Further, in a smart parking system, drivers can check the availability of parking spaces in a certain destination before arriving Smart parking systems can provide drivers the route to a specific parking area so that they can easily get there.
Although there is research into smart parking system technology [15], and there exist smart parking systems like SPARK [14], less research has been focused on algorithms for allocating scarce parking space. An exception is the work of [7] where authors used Mixed-Integer Linear Programming (MILP) to reduce the time to find a parking space. Yet there are more criteria that are relevant to allocate space in a fair way such as distance from destination, availability of parking spaces, pricing for reserving the parking space etc. The contribution of this works from taking users preferences into account. So that users will be allocated a parking space matching their preferences.
In this paper, we propose an algorithm for smart parking management system to achieve the above mentioned goal. This algorithm reserves a parking space for a user and the user can park at the reserved space without any need for searching. It is based on multiple criteria decision analysis (MCDA) [2] method. This algorithm uses three criteria to choose a parking space amongst several alternatives and suggests users to reserve most suitable parking space within their budget constraints. In this way the algorithm balances user preferences and owners of the parking areas.
The rest of the paper is organized as follows. Section 2 presents the related work. Proposed algorithm for reserving a space for parking is discussed in Section 3. In Section 4, detail illustrations are shown and simulation results are demonstrated in Section 5. A brief discussion about the algorithm is described in Section 6. Finally, the paper concludes in Section 7.

2 RELATED WORK

Smart parking is one of the domains of smart cities [20]. Idris et al. [8] provide a literature review of smart parking systems. Their work shows that most of the work in this field is focussed on sensor systems. In [12], a Smart Parking System is proposed to assists the drivers to find vacant spaces within a car park. The system uses ultrasonic sensors to detect whether vehicle is present or not in a parking slot. LEDs are used for different types of parking spaces. The LED display board shows how many vacant spaces are there at entrance of the car park.
A VANET based smart parking scheme [14] is proposed to provide parking service to the drivers in large parking lots. The proposed system manages the whole parking lot using VANET technology. Real time parking navigation service is provides to the drivers so that they can find vacant parking lots quickly. It also provides intelligent anti-theft protection service.
In [4], an optical star WSN based smart parking system is proposed. The proposed system consists of central server and several sensor nodes. They used optical sensor instead of loop detectors and count number of occupied space in parking space. Another related work based on WSN is proposed in [6]. The system monitors the availability of free parking slots and guides the vehicle to the nearest free slot. It also monitors the amount of time the vehicle has been parked for billing purposes.
In [21], authors proposed a reservation based smart parking system where drivers can find and reserve the vacant parking spaces. The drivers can use their personal communication devices to reserve the parking spaces. Another similar work is proposed in [19]. The authors proposed a smart parking guidance algorithm. The proposed algorithm supports drivers to find the most appropriate parking facility considering real-time status of parking facilities in a city.
Bonde et al. [3] focused to automate the car parking system by using Android application. The automated parking method allows the parking and exiting of cars using sensing devices. Entry to or exit from the car park is commanded by the application.
Pham et al. [16] introduce a smart parking system which is based on IoT and the paper presents a mathematical model for the system. The paper introduces an algorithm based on mathematical model so that user can find a free parking space at minimum cost. The proposed system forwards the vehicles to another car park if the current car park is full. The system maintains network of car park area where each car park is treated as a node and each node maintains the information of the neighbouring nodes so that it can forward the vehicle to other neighbour car park if it is full.
In [12] and [4], only concern about whether vehicle is present or not in the parking area and counting the number of available spaces in a particular car park area. In [12], driver can get the information of parking space availability only if user reaches to the car park spot. Hence, users have to go to other parking area which leads to wastage of time, cost and hampered traffic flow. There is no web service and hand held mobile application to guide the drivers about the availability of parking space [4] and [12]. In [16], the system offers the parking space to the driver's request keeping in mind only the cost factor and system will send hint message to the driver that the current car park is full in case there is no available space in current car park area. Then system again sends the other neighbouring park area of the current node. Hence it becomes difficult to select and reserve the parking area using mobile application while driving. Also the system is not concern about utilization of resources (parking area).
None of the algorithms take into account the user preferences. In the proposed algorithm presented in this paper user can easily find best car parking area in terms of distance between his/her destination and park area as well as car park price. Users have to provide the destination where he/she wants to go as well as he/she can provide priority like distance factor between parking area and destination, price of parking to the web service through android application. System will provide the best possible car park area to the user based on user's priority while maintaining proper resource utilization. No car park area will be overloaded or under loaded while allocation of parking spaces.

3 ALGORITHM DESIGN

The problem for parking space reservation should take into account user preferences, which are represented by multiple criteria. In this section we propose a Multiple Criteria based Parking space Reservation algorithm for smart parking system. The algorithm is named as MCPR. It is based on MCDA method. MCDA is an "umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter" [2].
The smart parking system has two main components 1) the users who want to reserve a space for their cars and which have a list of preferences and 2) the parking place owners. The later might be governments, but might also be companies who want to do earn money from the parking feeds.
The objective of the proposed algorithm is to find and reserve a parking space efficiently without wasting time considering better utilization of available parking spaces so that user of the system as well as resource (parking) owners both benefit. Amongst several parking areas the best suitable one is identified based on the destination location and other preferences given by the user. At the same time some people should be given priority (e.g. disabled people, hospital visit etc.). Therefore, this algorithm employs a distributed reservation to the mostly unoccupied parking areas considering the users' other criteria. In the next section overview of the MCDA method is described briefly.

3.1 Overview of MCDA

The MCDA method makes decision from various alternatives. These alternatives are ranked on the basis of different criteria used in the MCDA method. It is usually specified in terms of normalized weights for each criterion, as well as normalized scores for all options or alternatives relative to each criterion. The MCDA method is defined as follows.
It has a set of n alternatives with m criteria and the utility U for each alternative O_i is defined in the following equation as:

$$U(O_i) = \sum_{k=1}^{m} Z_k(O_i) \times W_k,\ i = 1, 2, ..., n \tag{1}$$

where, $Z_k(O_i)$ is the normalized score of alternative O_i under criterion C_k and W_k is the weight of importance for criterion C_k. The steps of the MCDA are as follows:

- Define criteria, C_k and alternatives, O_i
- For each criterion, find the range of each criterion values.

$$O_{kmin} = min\{(O_{ik}\ i = 1, 2, ..., n)\} for\ each\ C_k; k = 1, 2, ..., m \tag{2}$$

$$O_{kmax} = max\{(O_{ik}\ i = 1, 2, ..., n)\} for\ each\ C_k; k = 1, 2, ..., m \tag{3}$$

- Measure all criteria on similar numerical scales and normalize each criterion using the following equation.

$$Z_k(O_i) = ((O_{ik} - O_{kmin})/(O_{kmax} - O_{kmin})) \tag{4}$$

- Assign weights of importance W_k to the criteria and calculate the utility $U(O_i)$ for each alternative using Eq. 1.
- Rank alternatives in descending order of $U(O_i)$. The alternative with the highest utility U is the best alternative.

3.2 MCPR Algorithm

Each parking area has different number of parking spaces where vehicles can be parked. MCPR uses available parking spaces of certain parking area as a resource to satisfy the user's request for parking. The registered available parking areas are considered as the alternatives for this algorithm.
Let, the set of parking areas is denoted as $P = \{P_1, P_2...P_n\}$, where n is the number of available parking areas. Further, we consider each P_i has several parking spaces.
The objective of this algorithm is to find a parking space amongst these alternatives, P_i where $1 \leq i \leq n$.
The following assumptions are made for the algorithm being able to work.

- Each parking area equipped with ultrasonic sensors which will track whether parking slots or spaces are freed or occupied.
- Each parking area has local data collector unit which will collect total number of vehicles present at a particular time from the sensors.
- The local data collector transfers the status of the parking area in terms of number of vehicle presents, number of available parking spaces to the central web cloud server i.e. smart parking system.
- Each user has at least one smart ICT device like smart phones.

The working procedure for reservation of parking spaces is shown in Fig. 1. Initially, users give a request message to the system for reservation through their Smart phones. The reservation is made according to the users' requirement. The user can give information of their destination, maximum distance of parking area from destination and their desire pricing for the parking space. After getting the requests from users, the system finds the best suitable parking space using MCPR for the users as well as for the resource owners. If available space is found, then a positive response message with detail information of parking space is sent to the users' smart phone. If users are accepting the suggested parking spaces then they send an accepting message to the system and the system will update information of all the available resources accordingly.

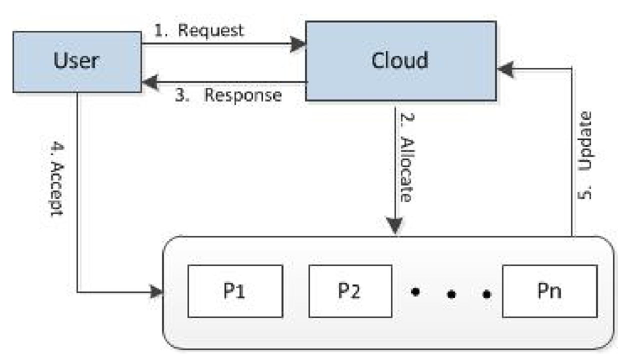

Figure 1: Work-Flow of the reservation process.

The procedure of the MCPR algorithm is explained as follows. The algorithm is run by the cloud server i.e. the smart parking system. MCPR considers the following three criteria:

- Distance between parking area and the destination. This is considered as criteria C1.
- Price per hour for reserving the space, i.e. criteria C2.
- Unoccupied space for each parking area and it is considered as criteria C3.

Depending on the user's requirement number of alternatives are vary dynamically or it may happen that system could not find any alternatives. Then the user may ask to give another new requirement.

4 ILLUSTRATION OF MCPR WITH EXAMPLES

In this illustration, the destination (given by the users where they want to go to) and the four parking areas are shown in Fig. 2. It is assumed that the user gives distance from the destination to the parking area within 2000 meter and cost for the parking space 50 rupees per hour. It is also assumed that each parking area may provide maximum of 200 parking spaces to park the vehicles. Table 1 shows the initial values of each available parking area (i.e. P1, P2, P3, P4 are alternatives for the MCPR algorithm) and criteria (C1, C2, C3) according to the user's choice which are used in this illustration.

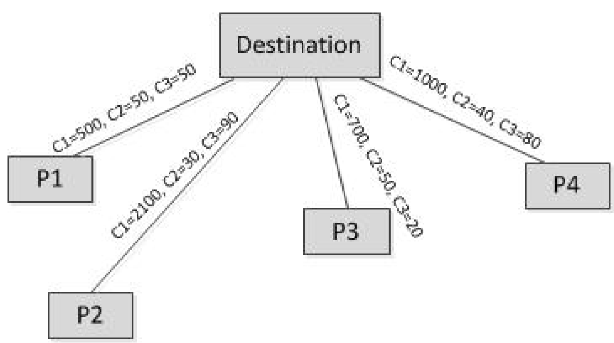

Figure 2: Example scenario of MCPR.

Table 1: Initial values of Alternatives and Criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	500	1900	700	1000
C2(rupee)	50	30	50	40
C3(space)	50	90	20	80

The steps of the methodology provided in the overview of MCDA section are applied here for the problem.

Step 1: Criteria and alternatives are defined in the Table 1.

Step 2: To measure all the three criteria same numerical scale is used i.e. a 0 to 100 scale. Initially, equal weight values are assigned to each criterion (C1, C2 and C3). Eq. 2 and Eq. 3 are used to find the minimum and maximum range of the each criterion. Minimum range and maximum range are defined as the worst value and the best value for the criteria respectively. Following values are considered are the minimum and maximum range for each criterion.

- Distance between Parking area and the destination (C1): The best value is considered as 0 meter i.e. parking area is next to the destination. It is most preferable parking area by the user. The worst value is 2000 meter, which is given by the user.
- Price per hour for reserving the space (C2): The best value for this criterion is zero rupee per hour. It is assumed for the free parking area. The worst value is 100 rupees per hour in this case.
- Unoccupied space for each parking area (C3): In this case the best value is 200 unoccupied spaces and worst value is 1 i.e. at least one space is still available to provide space to the user.

Step 3: After defining the minimum and maximum range of each criterion, the normalized values are obtained by using the Eq. 4 and absolute values are taken. Here, the calculation for all the three criteria of parking area P1 is explained. Therefore, for alternative P1, normalized value of criterion C1 is calculated as follows:

$Z_1(O_1) = (O_{11} - O_{1min})/(O_{1max} - O_{1min})$
$Z_1(O_1) = (500 - 2000)/(0 - 2000)$
$Z_1(O_1) = 0.75$

Similarly, for alternative P1, normalized values for criteria C2 and C3 are calculated as follows:

$Z_2(O_1) = (O_{12} - O_{2min})/(O_{2max} - O_{2min})$
$Z_2(O_1) = (50 - 100)/(0 - 100)$
$Z_2(O_1) = 0.50$
$Z_3(O_1) = (O_{13} - O_{3min})/(O_{3max} - O_{3min})$
$Z_3(O_1) = (50 - 1)/(200 - 1)$
$Z_3(O_1) = 0.2462$

Similar calculation approach is applied for alternatives P2, P3, and P4. All these values are measured in a same scale and final normalized values are provided in Table 2.

The utility U for each alternative O_i (P1, P2, P3, and P4 in this example) is calculated using the Eq. 1. Illustrative example for P1 is given as follows:

$$U(O_i) = \sum_{k=1}^{m} Z_k(O_i) \times W_k, \; i = 1, 2, ..., n$$

Here,

$U(O_1) = Z_1(O_1) \times W_1 + Z_2(O_1) \times W_2 + Z_3(O_1) \times W_3$
$U(O_1) = 75 \times 0.33 + 50 \times 0.33 + 24.62 \times 0.33$
$U(O_1) = 49.37$

Table 2: Normalized values of Alternatives and Criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	75	5	65	50
C2(rupee)	50	70	50	60
C3(space)	24.62	44.72	9.54	39.69

Similarly, for other parking areas, the utility values are obtained by the following equations and it is shown in Table 3.

$U(O_2) = Z_1(O_2) \times W_1 + Z_2(O_2) \times W_2 + Z_3(O_2) \times W_3$
$U(O_3) = Z_1(O_3) \times W_1 + Z_2(O_3) \times W_2 + Z_3(O_3) \times W_3$
$U(O_4) = Z_1(O_4) \times W_1 + Z_2(O_4) \times W_2 + Z_3(O_4) \times W_3$
After obtaining the final utility values, the alternatives are ranked in descending order of utility and it is presented in Table 4. From the table it is shown that parking area P4 is the most suitable one according to the user's need. The second suitable alternative is P1.

Table 3: Utility values of Alternatives

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	24.75	1.65	21.45	16.5
C2(rupee)	16.5	23.1	16.5	19.8
C3(space)	8.12	14.52	2.97	12.87
$U(O_i)$	49.37	39.5	41.1	49.4

Table 4: Descending order of Utility values

$U(O_i)$ in descending order	Parking area
39.5	P2
41.1	P3
49.37	P1
49.4	P4

Next some scenarios are given to explain the algorithm in more depth. The users' requests are continuous to the system. Now it might happen that for the same destination there are several users at the same time.

To explain the behaviour of the algorithm in such situations, two scenarios are taken namely *i) equal weight of criteria* and *ii) varying weight of criteria*. For equal weight of criteria, the users get the result for providing equal weight for all the criteria. None of them is more important than others. Users only give their destination location, desire distance from the destination and desire per hour price for reserving a space. In contrast, in the situation of having varying weight for criteria, user will get the results for the same situation while varying the weight (priority) of the criteria. In addition to the previous requirements, here users also give a certain weight to each criterion which will be used to select the parking space.

i) Scenario 1: Equal Weight of Criteria

In this case, it is assumed that the same requirements (i.e. same destination, same price for parking) are given to the system as mentioned in the above example. The current values for the available parking areas are given in the Table 5. Here only the difference is that parking area P4 is occupied with the two more cars than the previous scenario. Now P4 has 78 unoccupied spaces. Table 6 illustrates the final utility values for this scenario assuming equal weights are considered for all the three criteria. From the table it is clear that parking area P1 has the highest utility value and it is suggested parking area.

Therefore, from the previous two illustrations it is concluded that if there is no priority given to the criteria, the algorithm uses equal weights to the criteria. Further, for the same input requirements the algorithm fairly distributes the parking spaces of different parking areas to the users to maintain a balance between unoccupied parking spaces.

Table 5: Initial values of Alternatives having equal weight of criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	500	1900	700	1000
C2(rupee)	50	30	50	40
C3(space)	50	90	20	78

Table 6: Utility values of Alternatives having equal weight of criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	24.75	1.65	21.45	16.5
C2(rupee)	16.5	23.1	16.5	19.8
C3(space)	8.12	14.52	2.97	12.76
$U(O_i)$	49.37	39.5	41.1	49.0

ii) Scenario 2: Varying Weight of Criteria

In the previous scenario it is shown that parking area P1 is selected although there are available spaces in parking areas P3 and P4. This is because all the criteria have the equal weighted value. In varying weight of criteria, two cases are considered for varying the weights of the criteria. In Case 1, user gives the more priority on distance i.e. they want less walking distance from the destination to the parking area. In Case 2, users want to reduce the price for parking. They do not worry about the distance of parking area from the destination. Initial values are shown in Table 7. The following weights are considered for the criteria C1 and C2 respectively. Table 8 and Table 9 demonstrate the final utility values for Case 1 and Case 2 respectively. In Case 1, parking area P1 is chosen. In Case 2, criterion C1 becomes zero for all alternatives as multiplying factor $W1$ becomes zero. P2 is chosen in this case as it has lowest price for reserving a parking space.

- Case 1: $W1$= 50%. $W2$=25%.
- Case 2: $W1$= 0%, $W2$=80%.

Table 7: Initial values of Alternatives having varying weight of criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	500	1900	700	1000
C2(rupee)	50	30	50	40
C3(space)	50	90	20	78

Table 8: Utility values (Case 1) of Alternatives having varying weight of criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	37.5	2.5	32.5	25
C2(rupee)	12.5	17.5	12.5	15
C3(space)	6.15	11.18	2.38	9.67
$U(O_i)$	56.15	31.18	47.38	49.67

Table 9: Utility values (Case 2) of Alternatives having varying weight of criteria

Alternatives ⇒ Criteria ⇓	P1	P2	P3	P4
C1(meter)	0	0	0	0
C2(rupee)	40	56	40	48
C3(space)	4.92	8.8	1.92	7.73
$U(O_i)$	44.92	64.8	41.92	55.73

5 SIMULATION RESULTS

5.1 Simulation parameters

The simulation has been performed in MATLAB. The assumptions about the situations as shown in Table 10 are used for the simulation. For each set of the simulation we considered the Table 1 for the initial values for each of the parking area. The simulation is performed for 60 minutes, as this should give a sufficient insight into the performance of the algorithm and only static situation is considered. It is also assumed that users can request the same destination. To simulate the scenarios explained in Section 4, three preference sets are categorized for the simulation purpose. Preference-I represents Scenario 1 and Preference-II and Preference-III represent Scenario 2 where two cases of varying weight of criteria are considered.

- Preference-I: Equal weights for all three criteria (C1=0.33, C2=0.33, C3=0.33).
- Preference-II: More priority on distance from parking area to the destination. Less distance is preferable i.e. (C1=60%, C2=20%, C3=20%).
- Preference-III: More priority on price. Low price parking area is preferable i.e. (C1=20%, C2=60%, C3=20%).

Table 10: Simulation parameters

Parameters	Values
Simulation time	60 min
Parking areas	4
Destination	Same location (as shown in Fig. 2)
Preferences	3 (Pref-I, Pref-II, Pref-III)

5.2 Result and Analysis

In this work, the performance of the proposed algorithm has been assessed by the following metrics as below. The simulation results are shown in the Table 11.

Table 11: Simulation results

Preferences	Average walking distance(km/user)	Parking resources utilization rate (%)	
		Time(min)	value
I	0.77	10	0.725
		20	0.74
		30	0.76
		40	0.79
		50	0.82
		60	0.85
II	0.66	10	0.762
		20	0.762
		30	0.772
		40	0.8
		50	0.825
		60	0.86
III	1.19	10	0.725
		20	0.75
		30	0.77
		40	0.79
		50	0.823
		60	0.848

- Average walking distance: It is defined as the sum of walking distances of all users divided by the total number of users. The shorter walking distance is mostly preferred by the users since they want to park near the destination.
- Parking resource utilization rate: It is defined as the average occupied parking spaces at a certain simulation time with the total capacity of parking spaces in a particular parking area for same destination. The higher resource utilization rate means that resources are well utilized.
- Parking facility occupancy rate: It is defined as how efficiently each parking facility is utilized at each simulation time.

Fig. 3 shows the average walking distances for each of the preference. The table and figure show that Preference-II has the best value amongst the three preference sets. Every user wants to get the parking spaces near to the destination. In this preference set, user gives more priority on the criteria C1 i.e. distance from destination. On the other hand, Fig. 4, Fig. 5 and Fig. 6 show the parking facility occupancy rate for Preference-I, Preference-II and Preference-III respectively. It is clear from the Fig. 4 that occupancy rate for parking areas are fair. Furthermore, for preference-II in Fig. 5 the occupancy rate for parking spaces P1 and P3 are high as distance has more priority here. On the contrary, in Fig. 6 for preference-III, parking spaces P2 and P4 have higher occupancy rate.

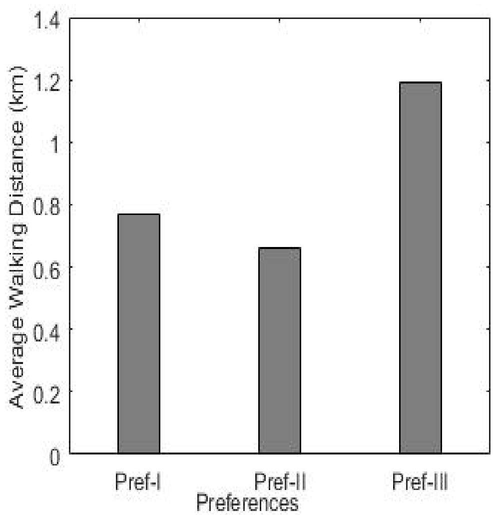

Figure 3: Average walking distance for each preference.

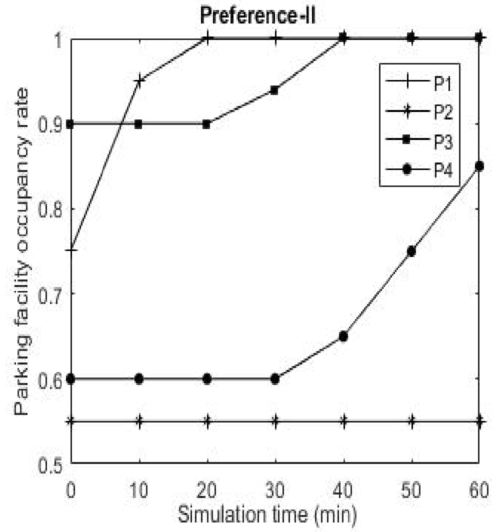

Figure 5: Parking facility utilization rate for Preference-II.

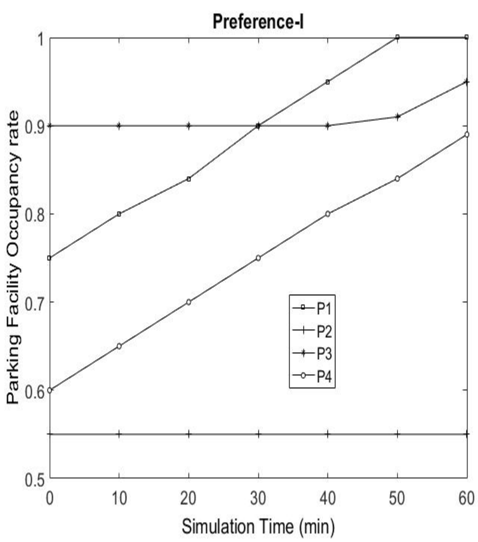

Figure 4: Parking facility utilization rate for Preference-I.

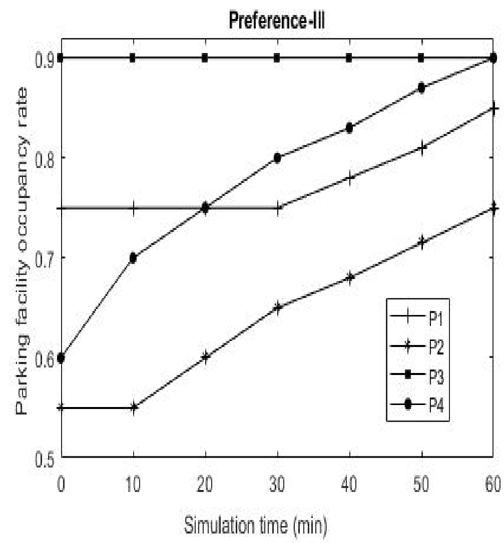

Figure 6: Parking facility utilization rate for Preference-III.

Fig. 7 shows the average utilization rate for each preference sets. Preference-II has the high utilization rate amongst them. As users prefer less walking distance between parking space and their destination, Preference-II is the best choice for them. On the other hand, when distance does not matter for the users and money is the main concern for the user, Preference-III is most suitable in that case. Further, even if, they are not giving any priority they can also get a fair parking space with equal weight of the criteria i.e. Preference-I. They can directly go to that parking space without having any delay. The smart parking system made equal distribution of reservation amongst the parking areas having same criteria (distance from the destination and per hour price rate) given by the users. That is the reason this preference is most sustainable choice for the smart parking system.

6 DISCUSSION

Smart parking systems make use of low cost sensors, real-time data and applications that allow users to find available parking space nearer to their destination. Smart parking solutions can encompass a complete suite of services such as online payments, parking time

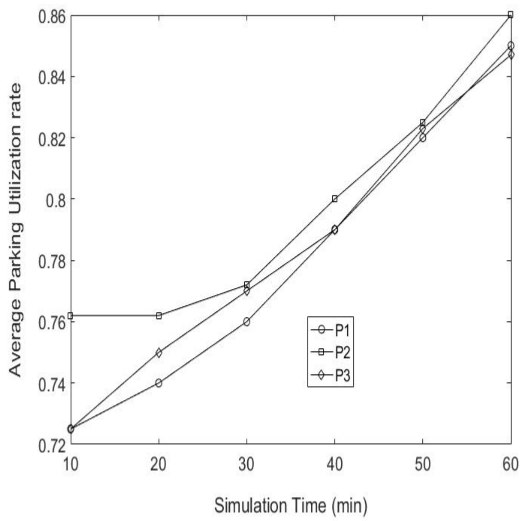

Figure 7: Average utilization rate for Preferences.

notifications and even car searching functionalities for very large lots. The MCPR algorithm presented in this paper finds the best suitable available parking space considering user preferences and the number of available parking spaces in the parking areas. The goal of this MCPR is to automate and decrease time spent manually searching for the suitable parking space. Instead of dealing with a single parking area, the algorithm is able to searching all parking areas nearer to the destination where the users wish to go. People and locations can be given different priorities. For example, disabled people can be given priority over other people and locations, like hospital, schools and tourist attractions, can be given different priorities. MCPR can greatly benefit both the user and the parking space owner. Benefits include the following:

- Balanced parking - Users find the best available space easily. The parking spaces fill up efficiently and space can be utilized properly by commercial and corporate entities.
- Save time - Users can shorten their parking search time and do not have to drive around.
- Reduced traffic - As fewer cars are moving around to search for parking spaces.
- Reduced Pollution - Searching for parking spaces requires drivers to accelerate and brake resulting in high levels of gas consumption. Smart parking systems can significantly decrease driving time, thus lowering the amount of daily vehicle emissions and ultimately reducing the global environmental footprint.

Although the implementation of a smart parking requires investments for any city government or company the benefits can outweigh the investments needed. As the global population continues to grow and urbanize, it is vital to implement a well-planned and convenience-driven parking solution that can be utilized, whereas the MCPR algorithms can be used to create a balanced parking policy taking into account societal and individual values.

7 CONCLUSION

The opening of data is essential part of smart cities initiatives. Yet, the simply opening of data might not yield the desired results. Merely, opening of parking data will not result in smart city objectives like less pollution and congestion. Smart parking faces the challenge of allocating scarce space in a fair way. This needs to balance the user preferences like the distance of the destination from the parking area, the per hour price for reserving the parking space and availability of the parking spaces. We proposed a Multi-Criteria decision analysis based Parking space Reservation (MCPR) algorithm to occupy a hassle free parking space near the destination. The preferences are represented by multiple-criteria. The algorithm balances the benefits of owners of parking areas and requirements of the users. Moreover, we have presented illustrations of the algorithm in detail and it also shown that it fairly distributes the parking spaces amongst the different users according to their needs. To understand the behaviour of the algorithm in different situations according to the users' requirements, three different preferences were simulated, e.g. Preference-I, Preference-II and Preference-III. The simulation shows that for each preference users can get a best suitable parking space according to their requirements and priority given to the criteria. Preference-II and Preference-III are suitable for having less walking distance to the destination from parking area and low pricing for parking area respectively. Preference-I gives the fair reservation of parking space and equal weighing of preferences resulting in the most sustainable choice for the smart parking system. This suggest that smart cities decision-makers should consider what they find more important, adhering to the user preferences or sustainability. Different smart cities might make different choices and our simulations provide insight into the effect.
The main advantages of MCPR algorithm is that it can be used to alleviate the traffic congestion problem during the searching the parking space, save time, reduce pollution and also user can book and get the information of the parking area near to the destination. Furthermore, in this work we did not take into account the duration of the reserved parking spaces nor did we look at dynamic pricing for reserving a parking space. We recommend to consider these elements in further research.

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