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Research Article

Parking Demand vs Supply: An Optimization-Based Approach at a University Campus

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Parking management has always been a major concern for universities and other activity centers. Nowadays, many universities are suffering from a lack of campus parking capacity. To tackle this problem, it is necessary to take parking lots assignment into consideration, regarding intercampus users' needs. These users have different ages, physical characteristics, expectations, and administrative positions that should be considered before any parking assignment. Here, a new method is proposed to optimize parking lots management for those universities where staff (academic and administrative), in contrast to students, are allowed to park inside the campus area. For this purpose, first, the probability of using a specific parking lot by each group is determined. For staff, this is done based on their choices, revealed by the relative frequency of using parking lots. This probability for students can be calculated using a fuzzy inference system model. To develop the model, a survey is conducted to extract students' preferences, regarding parking spaces assignment inside the campus area. Afterward, an integer linear programming model with the objective function of maximizing parking probability is employed, considering several related constraints. The proposed model is applied to Shahid Bahonar University of Kerman (SBUK), Iran, as the case study. According to the results, it can be concluded that the proposed method can help to reduce wandering time of finding an appropriate parking space for both staff and students. In addition, the proposed application can help increase the satisfaction level of staff and students with regard to parking management.

1. Introduction

Recently, the number of students as well as passenger car ownership has increased in an unprecedented rate. This has caused serious transportation problems for both inside and outside the university areas. Some of these universities are trying to tackle these challenges by employing transportation programs, policies, and practices [1]. Similarly, more effective travel demand management (TDM) measures should to be taken by universities in order to tackle, or at least curb, such kinds of traffic problems. Lack of a decent TDM program can impose unnecessary search time, traffic congestion, safety problems, interruption in pedestrian flow, noise and air pollution, fuel waste, disturbing the accessibility, and others [2, 3].

Parking management is considered as one of the most effective ways of TDM [4], which can provide suitable access to campus facilities [3]. Parking management helps universities to better use of the existing parking capacity by adopting more organized and sophisticated strategies. This approach has been proven to have positive impacts such as reducing demand for parking spaces, social equity, improving service efficiency and quality, and saving costs [5–7].

Intelligent Parking Systems (IPSs), as a subcategory of intelligent Transportation Systems (ITSs) and Advanced Traffic Management Systems (ATMSs), can be effective in managing and assigning parking lots in campus areas. IPS can help universities to assign parking lots in an optimum way and consequently reduce the externalities such as traffic congestion, search time, and inconvenience [8].

Different studies have been done about parking management for universities most of which have focused on parking pricing and its impact on mode choice of students. Parking pricing is a beneficial strategy whenever the demand for parking is greater than the supply. It can shift the travelers from passenger cars to sustainable transit modes [9–11].

Sweet and Ferguson [12] stated that travel demand management should be always considered in universities development, because of two main reasons. Not only are universities a major source of trip attraction but also they also have a moral responsibility toward their society. To implement a TDM inside university areas, restricting the parking supply and increasing the parking charge have always been the main countermeasures [12]. Aoun et al. [5] stated that conventional strategies like charging students for parking are unsuccessful in reducing parking demand and traffic congestion in American University of Beirut. They investigated the impacts of increasing parking supply and concluded that trips by passenger cars will be increased, which as a result heightens congestion problems [5]. dell'Olio et al. [13] tried to present a method to promote sustainable mobility in college campuses by implementing parking policies. They applied stated preferences and revealed preferences by a survey at Cantabria University in Spain. Using a mixed logit model, they concluded that parking pricing discourages students from using their passenger cars for trips to the university, which can help to improve sustainable transportation modes [13]. Barata et al. [2] evaluated parking management policies in University of Coimbra. The research intended to provide a plan for the proper use of parking spaces by considering variations in demand. In addition, parking pricing has been found to be useful in decreasing passenger cars deployment and covering parking management costs [2]. Bridgelall [14] evaluated the effect of parking supply and demand on mode choice in North Dakota State University. The results were successful in presenting a low cost and effective method, capable of determining changes in mode choice for different scenarios of parking supply and demand [14]. Meng et al. [15] studied parking choice behavior at Tongji University in Shanghai. Three scenarios were introduced for professors, staff, and students, including open-air, underground, and off-campus parking lots. The results indicated that parking lot factors including price, walking time, and number of free hours are significant in parking choice models. Additionally, demographics can also affect the parking choice model. According to the results, walking time was identified as the most influential factor in parking selection [15]. Tezcan [16] evaluated the effect of parking pricing on mode choice behavior in Ayazaga Campus of Istanbul Technical University. In this research, stated preferences and revealed preferences for willingness to pay have been extracted by providing different parking pricing scenarios. The results showed a significant shift from passenger cars to public transit if academicians are being charged for parking [16]. Proulx et al. [17] assessed the impact of parking pricing and transit fares on mode choice behavior in University of California, Berkeley. They concluded that parking pricing and increasing transit subsidies can be effective countermeasures in order to make a great shift from driving passenger cars to public transit. Furthermore, compared to changes in daily costs, changing the lifestyle of a group of commuters has been identified as a more effective approach [17].

Overall, a review of literature indicates that most of the previous studies, about parking management for universities, have focused on the pricing subject. They have evaluated the pricing details and its impact on discouraging students from using passenger cars and convincing them to use sustainable transportation systems. Besides, various groups with different institutional rankings, including professors, employees, and students, are the ones who utilize shared facilities on the university campus. These diverse groups have different expectations, and different priorities must be considered for devoting parking lots to these groups. In addition, during a day, demand for parking can be variable. On the other hand, there are limited parking spaces inside universities. All of these facts can affect parking assignment strategies and justify the need for a framework of optimizing the allocation of parking lots during a week.

This paper aims to propose a new optimization method for parking lots assignment in universities. With this regard, the main contribution of this paper is that it will increase our knowledge about developing an algorithm, which can be used in an intelligent web-based system to allocate parking lots to applicants in a university campus. The main assumption in this method is that in contrast to staff, students are not permitted to park inside the organization. However, there are enough parking spaces to accommodate a group of students in most of the time intervals during a week. The students must pay charges for parking spaces. The model tries to increase the satisfaction of students and staff simultaneously. It also aims to decrease the time for finding a suitable parking. The model can consider the priority of different groups (professors, employees, Ph.D. students, M.Sc. students, and B.Sc. students), variations in demand (during different time intervals a day), parking pricing (for students), and frequency of parking supply at each time interval for parking assignment. To the best of the authors' knowledge, this approach has never been used in the previous studies.

The paper has 6 sections. In the following section, an explanation of the procedure for developing ILP model is presented. Then, the case study will be illustrated. The optimization results and its advantages are presented for one workday in the case study. This is followed by the discussion and conclusion.

2. Methodology

This study seeks to help developing a web-based application, to enhance assigning parking lots to applicants in an optimized and real-time manner in the universities, considering the priorities of each group, limitations about parking lots' capacity, demand variation, and parking pricing among others.

Parking assignment is a decision making process, which can be done by scientific methods like mathematical programming. Mathematical programming is a powerful method to solve optimization problems. There are different mathematical programming methods such as linear programming (LP), dynamic programming (DP), binary programming (BP), Quadratic Programming (QP), Quadratic Constrained Programming (QCP), Mathematical Program with Complementarity Constraints (MPCCs), and integer linear programming (ILP). Each method must be used in relation to a specific problem.

LP is one of the most powerful and widely used mathematical tools in solving optimization problems. LP is a suitable method for solving problems, which deals with resource allocation and scheduling [18, 19]. The main advantage of LP is its simplicity and robustness. Each LP consists of decision variables, objective functions, and constraints. ILP is a kind of LP in which all of the decision variables are integers the same as number of vehicles assigned to a specific parking lot. Here, ILP is used to assign parking lots to students and staff.

ILP is a popular tool for solving optimization problems. Previously, some papers have used ILP to solve other problems in relation to parking. For example, Abdelfatah and Taha tried to find the optimal angle and size of parking spaces by ILP to increase the parking capacity [20]. Sentia et al. [21] used ILP again to find the optimal layout of the parking area in a mall [21]. In another research, Levin [22] used ILP to assign vehicles to different routes in a road network based on the congestion in each route and parking lots reserved by each vehicle. The objective was to minimize the travel time in a network by decreasing the time both in-vehicle and out-of-vehicle [22].

The reasons for using ILP in this study are as follows:

(i) The research problem deals with an optimization issue

(ii) The constraints and objective function are all linear

(iii) All of the variables are restricted to be integers

(iv) There are certain choices as parking lots

(v) The ILP is a simple and easy to understand method

In the ILP model, the objective is to allocate vehicles from different divisions, to specific parking lots at each time interval; thus, the decision variable is X_{ijk}. The objective function is to maximizing the weight of parking in a specific parking lot. The weight of parking in a specific parking lot by different groups at various time intervals is considered equal to the probability of parking (P_{ijk}). The main constraints at each time interval in the ILP model consist of these items:

(i) Considering the capacity of each parking lot

(ii) Providing parking spaces for staff in accordance to their preferences

(iii) Providing enough parking spaces for staff of different divisions who require parking

(iv) Parking spaces devoted to students should not be more than their demand

(v) Regarding priorities for assigning parking spaces among students based on their educational level

To develop the ILP model, at first, the probability of parking in a specific parking lot must be determined (P_{ijk}). In contrast to students, the staff are permissible to park inside the university (the main assumption of the research). Thus, for the staff of various divisions, the revealed preferences for parking inside the university are known. The probability of parking at each parking lot in different time intervals can be determined by a data collection for staff and identifying the relative frequency of using each parking lot. However, for students, their preferences must be extracted by a questionnaire. Socioeconomic characteristics of students and parking specifications can be effective on the determination of their parking probability. These characteristics consist of the distance between parking lots and departments, education level, monthly income, total hours being in the university weekly, daily walking time, and parking cost.

To determine these input variables, in a survey, we have asked each student, what factors can be effective for choosing a parking lot inside the university. In addition, we have asked them to devote a score as importance of each variable from zero to 100. Then, analyzing data the most repeated variables with the highest scores have been selected. The justification for using these variables for calculating the probability of parking inside the university is as follows:

(i) The parking cost is important since the parking spaces outside the university are free and often pricing for transportation facilities can affect the probability of their usage.

(ii) Monthly income is important since the higher the income is the higher chance there is to use a parking space with a specific charge.

(iii) The parking spaces inside the university have specific charges but those, which are outside are free. One of the main advantages of the inside parking spaces is their distance to the departments. Thus, the closer the parking lot is to the destination, the more likely it to be chosen.

(iv) The higher the level of education is, the higher social and institutional dignity would be. Thus, their preference for using parking lots inside the university can increase.

(v) Those students who spend more time in the university prefer to park inside the campus because of security reasons.

(vi) Those students who walk more frequently are more susceptible to park outside the university and walk to their departments.

Here, Mamdani-type of fuzzy inference system (FIS) is applied to determine P_{ijk} for students. Mamdani-type inference expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable, which needs defuzzification (؟؟؟).

FIS is used to systematically describe human knowledge and from it to infer and make the proper decision. In addition, it attempts to achieve a certain output based on imprecise terms similar to the way the human brain functions. The basic structure of FIS consists of three conceptual parts. The first part involves the rules, in the form of a series of if-then orders, which provide a combination of inputs and outputs. The second part is a database that defines the membership functions used in fuzzy rules. The third part is the mechanism that carries out the inference procedure using existing rules and facts to generate a reasonable output [23].

Accordingly, in the present study, the inputs are the distance between parking lots and departments, education level, monthly income, total hours being in the university weekly, daily walking time, and parking cost. The desired output is the probability of parking in a specific parking lot. Membership functions for input indices are considered Gaussian. Gaussian functions have a feature that considers changes in the target function softly and slowly for each of the input variables. The Gaussian membership functions for input variables are demonstrated in Figure 1.

Membership functions quantify the grade of membership of an element to a fuzzy set. The membership values are in the range of 0 to 1. For example, in Figure 1, there are three fuzzy sets as Low, Medium, and High for the monthly income variable. Range of changes for this variable is 50 to 800. Now, for each value in this range based on Gaussian membership functions, we can determine the membership value to each set. For example, 200 belongs to the Low set about 50 percent, to Medium set about 20 percent and to High set 0 percent.

FIS rules explain the relationship between different combinations of input variables with the output variable in the form of linguistic variables. Fuzzy rules are in the form of If-Then statements. The "If" part called the antecedent and the "Then" part called the consequent. In the Mamdani fuzzy inference system, there are two operations, which are "And" ("min") and "Or" ("max"). In order to develop fuzzy rules, the attitudes of students about parking in different parking lots are required. For this purpose, a questionnaire is provided and students will be interviewed. By combining the input variables, different rules can be obtained.

By combining the input variables, 729 rules have been obtained, but for the aim of abbreviation, just 10 rules are displayed in Table 1 as an illustration.

P_{ijk} will be determined for each student from department j to park in the ith parking lot, with the help of the FIS model. It should be recalled that to calculate P_{ijk} for staff, we used the relative frequency of parking in each parking lot during a week. After specifying the values of right-hand sides and other coefficients, the ILP model can be run.

Now, the details for ILP model consist of decision variable, objective function, and constraints are identified as Table 2.

In order to pursue the methodological steps, a flowchart is presented in Figure 2.

3. Case Study

This section discusses how the proposed model is applied to Shahid Bahonar University of Kerman (SBUK). SBUK is a research institution and university of engineering and science, offering both undergraduate and postgraduate studies in Kerman. The university is one of the top ten universities and research institutes in Iran, confirming its significant position in research and education. SBUK occupies an area of 5 million square meters, making it one of the largest universities in Iran and the region, offering degrees in over 100 different specialties. The university has about twelve-thousand students and researchers, six-hundred professors, and seven-hundred employees and workers. Each day, especially during peak-hours, the main street in front of the university confronting jam densities and it is hard to find a proper and secure parking space.

Parking management in SBUK, because of its extensiveness and the high number of users, is a complicated task and needs a mathematical optimization modeling. The model must consider the priority of different groups (professors, employees, Ph.D. students, M.Sc. students, and B.Sc. students), variations in demand (during different time intervals a day), parking pricing (for students), and frequency of parking supply at each time interval. SBUK needs a web-based application to allocate parking spaces inside the university to different groups in an optimal and real-time manner. Each user (both staff and students) must request for a parking lot in the application for each day. It should be mentioned that even staff must request for parking lots. This has two reasons; first, because we have divisions in the University campus that can park in different parking lots and second it relates to the fact that we are devoting remained parking spaces to students at each time interval.

We need input data to provide the information about the demand during a week and for running the model. However, this makes it hard for those staff and students who come to the University campus frequently. Therefore, we can provide options for registering the request for parking for a week or a month or even semester for such applicants. On the other hand, for those who come less to the University campus, daily reservations can be considered.

Then, based on the proposed ILP model, parking lots assignment can be done. This can help decreasing time for finding a suitable parking and increasing satisfaction from parking management. Currently, in contrast to staff, students are not permitted to park inside the campus. Nevertheless, there are enough parking spaces to accommodate a group of students in most of the time intervals during a week.

The general form of the proposed ILP has been introduced in Table 1; now, the paper seeks to apply that model to SBUK. There are nine parking lots in the university as displayed in Figure 3, so that i in the decision variable changes from 1 to 9. Each parking lot also contains parking spaces as presented in Table 3.

Workdays are from Saturday to Wednesday from 7:30 to 17:30. Table 4 indicates time intervals during a day. These time intervals have been selected based on the times that classes begin and end in SBUK. Most of the undergraduate students move toward the university to attend the classes. The postgraduate students also have some classrooms in the first year of their education. Other students also usually go to

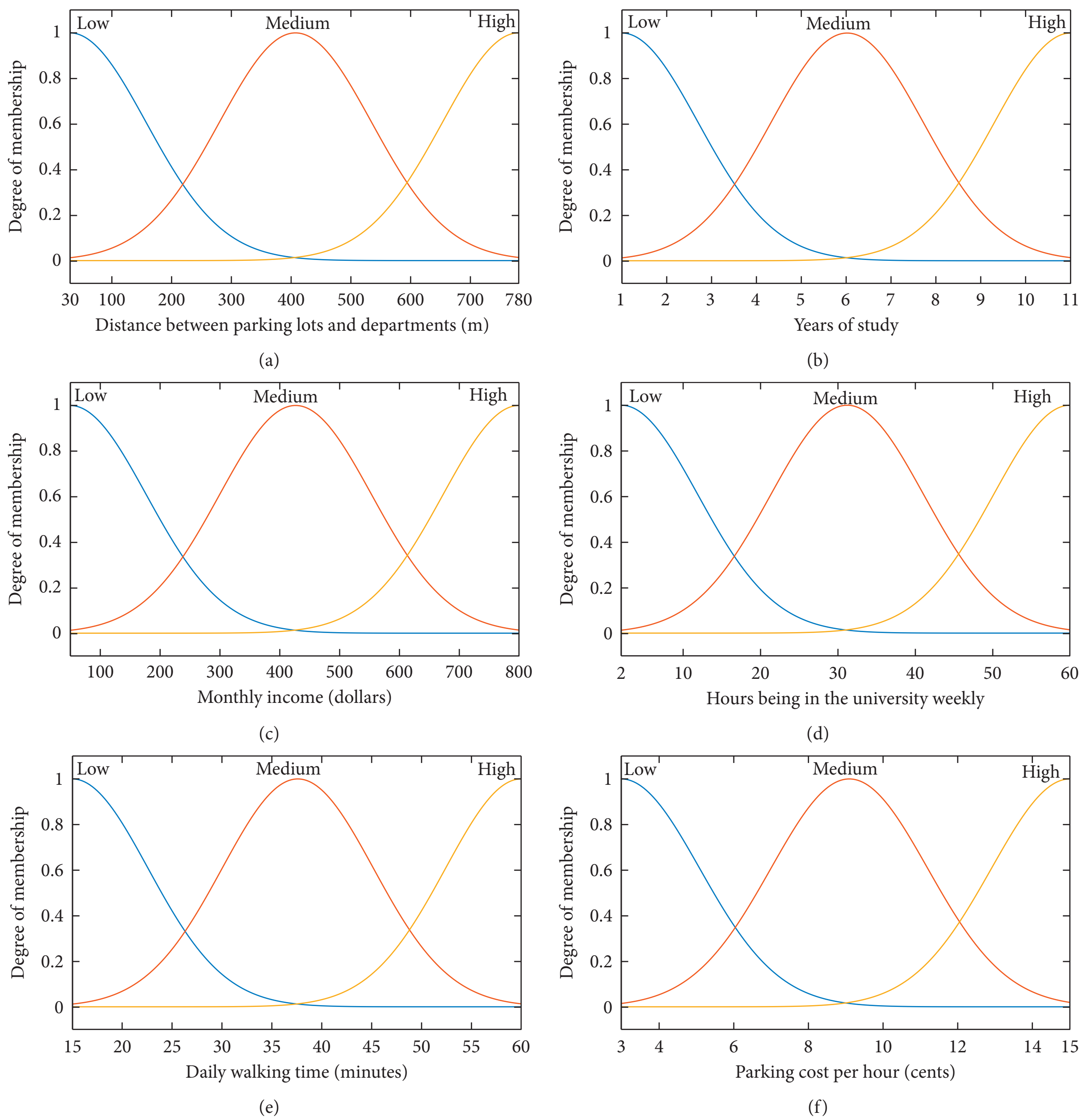

Figure 1: Input membership functions for modelling using fuzzy inference system.

university to meet professors. They must try to set their time to meet the professors before or after each class.

Thus, k in the decision variable ranges from 1 to 5 for each day in Table 4.

Based on the previous explanations, there are two distinct groups in the ILP. The first group includes employees of different departments and the second one contains students. In the SBUK, first group consists of 16 subdivisions as displayed in Table 5. Currently, employees of different divisions tend to park their vehicles in the parking lots as described in Table 6.

To calculate P_{ijk} for students, a FIS model is used. The input variables and their range of changes are as Table 7 for SBUK. The desired output is the probability of parking in a specific parking lot.

Now, it can be declared that j in the ILP model ranges from 1 to 988. In Table 5, $j = 1$ to $j = 16$ have been presented for staff. Now, $j = 17$ to $j = 988$, which relate to students, are displayed in Table 8. These categories are obtained based on the combination of educational level, monthly income, hours being in the university for a week, and daily walking time. Parking cost depends on the entrance time. Furthermore, the distance between parking lot and departments relates to the assigned parking position. Therefore, these two variables have not been considered in the determination of student groups.

Each student belongs to a specific department from S_1 to S_{12} and S_{13} to S_{16} are not the primary destinations of students. Therefore, in an assortment of students in Table 8, just S_1 to S_{12} are considered.

Table 1: Fuzzy rules to determine probability of parking by students.

Row	D, E, I, H, W, C						Parking probability
1	Low	Low	Low	Low	Low	Low	High
2	Low	Low	Low	Low	Medium	Low	High
3	Low	Low	Low	Low	Medium	Medium	High
4	Low	Low	Low	Low	Medium	High	High
5	Low	Low	Low	Medium	Medium	Low	High
6	Low	Low	Low	Medium	Medium	Medium	High
7	Low	Low	Low	Medium	Medium	High	High
8	Low	Low	Low	Medium	Medium	Low	Medium
9	Low	Low	Low	Medium	Medium	Low	High
10	Low	Low	Low	High	Medium	High	High

D: distance between parking lots and departments; E: education level; I: monthly income or the money they receive from the family; H: total hours being in the university weekly; W: daily walking time; C: parking cost per hour.

Table 2: ILP details for parking optimization.

ILP elements	Details	Description
Decision variable	$X_{i,j,k}$	Number of vehicles assigned to the ith parking lot from jth category at kth time interval
Objective function	$\operatorname{Max} Y = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} P_{i,j,k} \cdot X_{i,j,k}$	$P_{i,j,k}$: probability of parking in the ith parking lot by jth category at kth time interval
Group constraints 1	Capacity of each parking lot must be considered Percent of vehicle stay in a specific parking lot from previous time intervals also must be considered in the calculation process	
Group constraints 2	Each parking lot must be available for the related staff of each department at different time intervals	
Group constraints 3	The total demand from staff of different departments must be met	
Group constraints 4	Number of parking spaces devoted to students of each department at different time intervals must be equal or less than the applicants from that department	
Group constraints 5	Parking spaces devoted to students of each department must be divided between students based on their education level at each time interval	

In order to determine P_{ijk} for staff, the relative frequency of using each parking lot by them during a day is needed. For this purpose, the revealed preferences for staff have been collected in SBUK.

Now Table 2 can be rewritten with all details for SBUK as Table 9.

The sample size to be surveyed with the questionnaires is determined by the following equation [24]:

$$n \geq N\left[1 + \frac{N-1}{pq}\left(\frac{d}{Z_{\alpha/2}}\right)^{2}\right]^{-1}, \tag{1}$$

where n is the sample size, number of students, and staff for data collection, N is the population size, number of total staff, and students in the university campus, Z is 1.96 for 95% confidence level, p; q is the quality characteristics which are to be measured. Where no previous experience exists, the value of p is taken as 0.5 and $q = 1 - p = 0.5$; d is the desired level of precision and is considered 6.5%.

The sample sizes for students and staff were calculated based on the population of 12,000 students, 1300 staff (academic and administrative), margin of error of 6.5%, and confidence level of 95%. More than 224 students and 194 staff must be assessed based on the mentioned input values. In this paper, data for 250 students and 200 staff were collected.

4. Results

In this part, first, the parameters relating to the ILP model are determined for SBUK. Then, regarding the demands in each interval during a week, the model is solved. Based on the staff choices and students' preferences, it can be concluded that travel pattern is different from day to day in SBUK. Therefore, the model details also must be different for each day. The same procedure can be applied for all days. It should be mentioned that the demand can change for each day and each semester based on the students' courses schedule. However, this study solely considered the procedure for Saturdays in a specific semester, which started in September 2019 and ends in January 2020.

The survey was done in two months from October to November 2019. It was tried to survey the students in different departments and from different education levels. The samples have been selected in random in each department. At the end of each week, the frequency of the samples based on their attributes as demonstrated in Table 7 was evaluated. Then, in the next week, the focus was to survey the students based on those attributes with less frequencies to complete the database.

α_{xy}, β_{xy}, γ_{xy}, λ_{xy}, μ_{xy}, τ_{xy}, σ_{xy}, ζ_{xy}, and θ_{xy} are the percent of vehicles, which stay in Z_1 to Z_9 from time interval

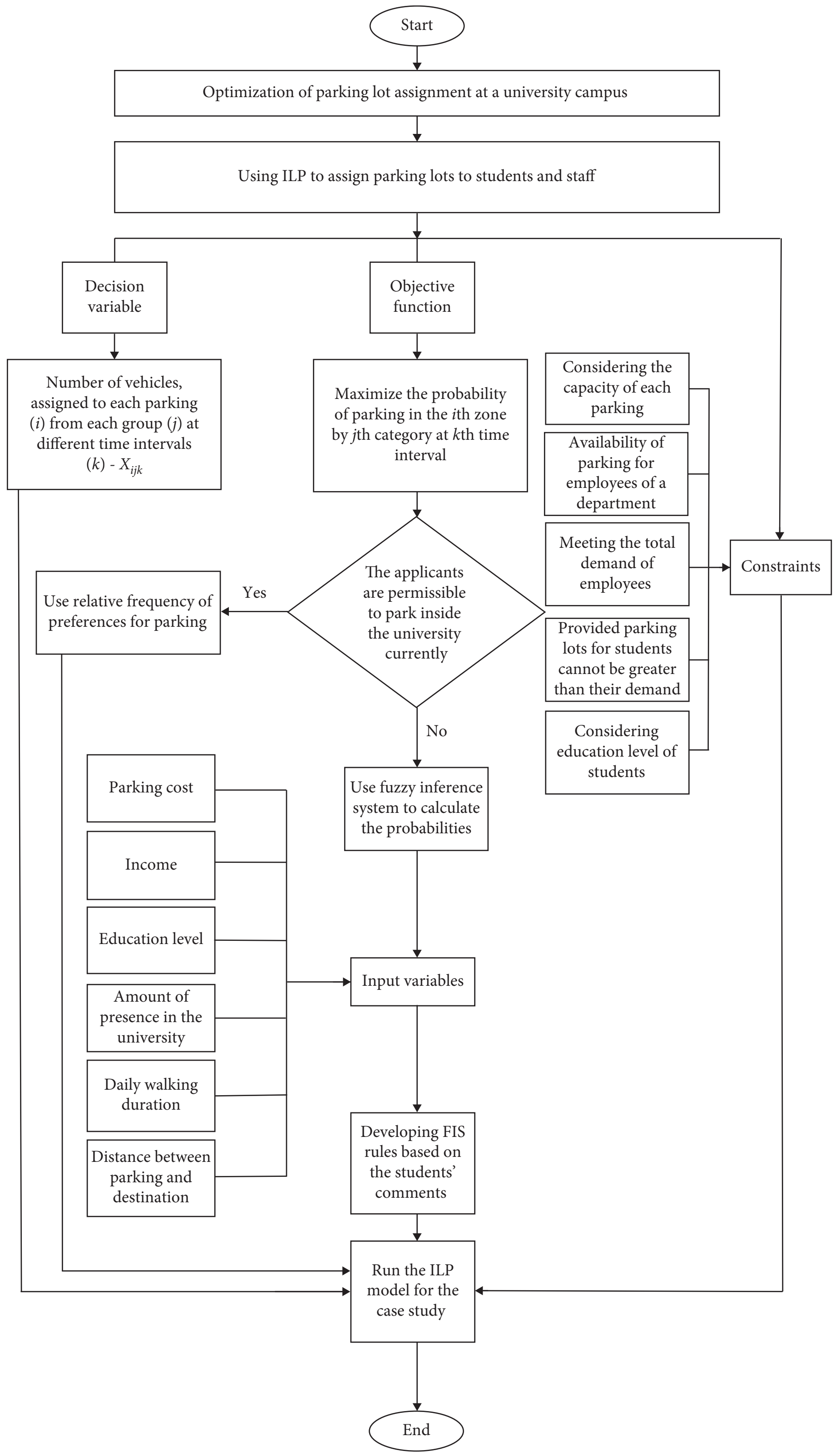

Figure 2: Research flowchart.

x to y. Based on the data collected for staff by field observations and data collected for students by the questionnaire, the values for these parameters are as given in Table 10.

In addition, the frequency of staff, who are applicants for parking in each parking lot at different intervals, is displayed in Table 11. Data have been collected based on field

Figure 3: Parking lots in SBUK.

Table 3: Capacity of each parking lot.

Parking lot	Parking name	Capacity of parking lot
1	Mathematics (Z_1)	130
2	Engineering (Z_2)	80
3	Dining hall (Z_3)	90
4	Medical science (Z_4)	100
5	Students' affairs (Z_5)	15
6	Veterinary medicine (Z_6)	30
7	Arts (Z_7)	80
8	Agriculture (Z_8)	40
9	Economics (Z_9)	50

Table 4: Time intervals during workdays of a week (k).

Time interval	Code
7:30–9:30	1
9:30–11:30	2
11:30–13:30	3
13:30–15:30	4
15:30–17:30	5

Table 5: Classification of staff (j).

Category (j)	Division
1	Arts and architecture department (S_1)
2	Mathematics and computer science department (S_2)
3	Literature and humanities department (S_3)
4	Law and theology department (S_4)
5	Physics department (S_5)
6	Sciences department (S_6)
7	Agriculture department (S_7)
8	Medical sciences department (S_8)
9	Veterinary medicine department (S_9)
10	Physical education department (S_{10})
11	Engineering department (S_{11})
12	Management and economics department (S_{12})
13	Students' affairs office (S_{13})
14	Central library (S_{14})
15	Deputy of education and graduate studies (S_{15})
16	Dining halls (S_{16})

observations. For the aim of brevity, just a part of these frequencies are presented.

P_{ijk} for staff would be determined by calculating relative frequencies based on Table 11. P_{ijk} for students will be determined with the help of detailed data relating to students as indicated in Table 8 and FIS model. Parking cost for $k = 1$ to $k = 5$ is considered as in Table 12, based on the demand for parking inside the university.

The distance between departments and parking lots is calculated also for each student. Therefore, all input variables in Table 7 will be achieved to calculate P_{ijk} for students by the FIS model. Distribution of demand from students and staff on Saturdays is as in Table 13.

The ILP results to assign parking spaces in each parking lot to staff and students for Saturdays are as in Table 14. The same procedure would be repeated for the whole week.

The model can be run in less than 3 seconds, and there is not any computational complexity in this model. One of the advantages of the ILP models is their simplicity and run time.

In order to evaluate the efficiency of the proposed method for parking lots' assignment with the current status, two indicators are considered. The first indicator is wandering time to find an appropriate parking space, and the second one is the satisfaction of applicants from parking management.

Wandering time represents the time it takes to find available parking space after entering the parking lot. This time is determined for two periods before and after using the

Table 6: Manner by which staff use different parking lots.

Category	Division	Parking lot
1	S_1	Z_7
2	S_2	Z_1, Z_2
3	S_3	Z_1, Z_2
4	S_4	Z_1
5	S_5	Z_3
6	S_6	Z_3
7	S_7	Z_4, Z_8
8	S_8	Z_4
9	S_9	Z_6
10	S_{10}	Z_6
11	S_{11}	Z_2, Z_4
12	S_{12}	Z_9
13	S_{13}	Z_5
14	S_{14}	Z_4, Z_2, Z_8
15	S_{15}	Z_7
16	S_{16}	Z_3

Table 7: Range of changes for input variables related to the FIS model.

Variable	Range	Unit
Distance between parking lots and departments (D)	30–780	Meter
Education level (E)	1–11	Years of study
Monthly income or the money they receive from the family (I)	50–800	Dollars
Total hours being in the university weekly (H)	2–60	Hours
Daily walking time (W)	15–60	Minutes
Parking cost per hour (C)	3–15	Cents

Table 8: Students' groups in SBUK for parking assignment (j).

Department	Socioeconomic factors	Divisions	j
	Educational level	B.Sc.	
	Income	Low	
1	Total hours being in the university weekly	Low	17
	Daily walking time	Low	
	Educational level	B.Sc.	
	Income	Low	
1	Total hours being in the university weekly	Low	18
	Daily walking time	Medium	
. . .			
	Educational level	Ph.D.	
	Income	High	
12	Total hours being in the university weekly	High	988
	Daily walking time	High	

proposed scheme for parking assignments. For this purpose, we have asked staff and students about the time that they spend for finding a proper parking space. For staff, the average of wandering time after using this application was almost zero. But, for students, it was greater than zero, since again a group of them must try to find a parking space outside the University campus and then the system has not devoted any parking space inside.

We have evaluated these indicators for 20 staff and 70 students, which have been selected by random. Table 15 indicates average of the results for these two indicators for students and staff. Satisfaction has been posed as an ordinal variable with these options: very low, low, medium, high, and very high.

In addition, a t test was used to compare the means for wandering time and satisfaction. The mean differences for wandering time and satisfaction are presented in Table 15. For satisfaction, we have used the numbers 1 to 5 to reflect very high to very low scales.

5. Discussion

Based on the results of Table 15, it can be declared that the proposed model can be an appropriate framework for parking management in the SBUK. As can be observed in Table 14, it is possible to accommodate some students inside the university at different time intervals. This procedure can be beneficial for better exploitation of parking lots by considering institutional rankings and expectations. This will help decreasing wandering time for searching a proper parking and dissatisfaction from parking management. Briefly, the main objective of this paper was to propose a method to assign parking spaces to students and staff in a university by considering the institutional positions, education level, parking capacity, and other considerations. We wanted to use the current capacity of parking lots to accommodate a group of students inside the university campus. At the same time, we did not aim to improve the utility of passenger cars for students to attract them from sustainable transportation systems. The overall purpose of this study was to decrease

Table 9: ILP for parking optimization.

ILP elements	Details	Description
Decision variable	$X_{i,j,k}$	Number of vehicles assigned to the ith parking lot from jth category at kth time interval
Objective function	$\text{Max } Y = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} P_{i,j,k} \cdot X_{i,j,k}$	$P_{i,j,k}$: probability of parking in the ith parking lot by jth category at kth time interval
Constraint 1	$\begin{cases} \sum_{j=1}^{988} X_{1,j,1} \leq 130, \\ \alpha_{12} \sum_{j=1}^{988} X_{1,j,1} + \sum_{j=1}^{988} X_{1,j,2} \leq 130, \\ \cdots \\ \alpha_{15} \sum_{j=1}^{988} X_{1,j,1} + \alpha_{25} \sum_{j=1}^{988} X_{1,j,2} + \alpha_{35} \sum_{j=1}^{988} X_{1,j,3} + \alpha_{45} \sum_{j=1}^{988} X_{1,j,4} + \sum_{j=1}^{988} X_{1,j,5} \leq 130, \end{cases}$	Capacity of Z_1 must be considered; α_{xy} indicates percent of vehicle stay in Z_1 from time interval x to y
Constraints 2 to 9 are the same as constraint 1 but for parking lots 2 to 9		
Constraint 10	$\begin{cases} X_{1,2,1} + X_{1,3,1} + X_{1,4,1} \geq A_{2,1} + A_{3,1} + A_{4,1} \\ \cdots \\ X_{1,2,5} + X_{1,3,5} + X_{1,4,5} \geq A_{2,5} + A_{3,5} + A_{4,5} \end{cases}$	Z_1 must be available for the related staff (based on Table 6); $A_{j,k}$ is the number of applicants from category j at time interval k for Z_1
Constraints 11 to 18 are the same as constraint 10 but for parking lots 2 to 9		
Constraint 19	$\begin{cases} \sum_{i=1}^{9} X_{i,1,1} = A'_1, \\ \vdots \\ \sum_{i=1}^{9} X_{i,1,5} = A'_5, \end{cases}$	Parking spaces must be available for the staff who are applicants from S_1 at time interval k; A'_k are the total number of applicants from S_1 at time interval k
Constraints 20 to 34 are the same as constraint 19 but for departments 2 to 16		
Constraint 35	$\begin{cases} \sum_{i=1}^{9} \sum_{j=17}^{97} X_{i,j,1} \leq a_{1,1}, \\ \vdots \\ \sum_{i=1}^{9} \sum_{j=17}^{97} X_{i,j,5} \leq a_{1,5}, \end{cases}$	Number of parking spaces devoted to students of S_1 at time interval k must be less than applicants from this department; $a_{1,k}$ is the number of applicants from department 1 at time interval k
Constraints 36 to 46 are the same as constraint 35 but for departments 2 to 12		
Constraint 47	$\begin{cases} \sum_{i=1}^{9} \sum_{j=71}^{97} X_{i,j,1} = 2 \sum_{i=1}^{9} \sum_{j=44}^{70} X_{i,j,1} \ \& \ \sum_{i=1}^{9} \sum_{j=44}^{70} X_{i,j,1} = 3 \sum_{i=1}^{9} \sum_{j=17}^{43} X_{i,j,1} \\ \vdots \\ \sum_{i=1}^{9} \sum_{j=71}^{97} X_{i,j,5} = 2 \sum_{i=1}^{9} \sum_{j=44}^{70} X_{i,j,5} \ \& \ \sum_{i=1}^{9} \sum_{j=44}^{70} X_{i,j,5} = 3 \sum_{i=1}^{9} \sum_{j=17}^{43} X_{i,j,5} \end{cases}$	Parking spaces devoted to students of S_1 must be divided in this manner at each time interval: 60% Ph.D. students, 30% M.Sc, and 10% B.Sc
Constraints 48 to 58 are the same as constraint 47 but for departments 2 to 12		

Table 10: Percent of vehicles remain in a parking lot from one interval to another one.

$\alpha_{x,y}$				$\beta_{x,y}$				$\gamma_{x,y}$			
$\alpha_{1,2} = 100$				$\beta_{1,2} = 100$				$\gamma_{1,2} = 100$			
$\alpha_{1,3} = 100$	$\alpha_{2,3} = 100$			$\beta_{1,3} = 87$	$\beta_{2,3} = 87$			$\gamma_{1,3} = 100$	$\gamma_{2,3} = 100$		
$\alpha_{1,4} = 90$	$\alpha_{2,4} = 100$	$\alpha_{3,4} = 100$		$\beta_{1,4} = 67$	$\beta_{2,4} = 67$	$\beta_{3,4} = 69$		$\gamma_{1,4} = 89$	$\gamma_{2,4} = 90$	$\gamma_{3,4} = 9090$	
$\alpha_{1,5} = 40$	$\alpha_{2,5} = 27$	$\alpha_{3,5} = 27$	$\alpha_{4,5} = 34$	$\beta_{1,5} = 20$	$\beta_{2,5} = 20$	$\beta_{3,5} = 23$	$\beta_{4,5} = 20$	$\gamma_{1,5} = 11$	$\gamma_{2,5} = 20$	$\gamma_{3,5} = 20$	$\gamma_{4,5} = 23$
$\lambda_{x,y}$				$\mu_{x,y}$				$\tau_{x,y}$			
$\lambda_{1,2} = 100$				$\mu_{1,2} = 100$				$\tau_{1,2} = 100$			
$\lambda_{1,3} = 100$	$\lambda_{2,3} = 100$			$\mu_{1,3} = 100$	$\mu_{2,3} = 100$			$\tau_{1,3} = 100$	$\tau_{2,3} = 100$		
$\lambda_{1,4} = 90$	$\lambda_{2,4} = 90$	$\lambda_{3,4} = 90$		$\mu_{1,4} = 100$	$\mu_{2,4} = 100$	$\mu_{3,4} = 100$		$\tau_{1,4} = 90$	$\tau_{2,4} = 90$	$\tau_{3,4} = 90$	
$\lambda_{1,5} = 25$	$\lambda_{2,5} = 25$	$\lambda_{3,5} = 25$	$\lambda_{4,5} = 27$	$\mu_{1,5} = 10$	$\mu_{2,5} = 10$	$\mu_{3,5} = 10$	$\mu_{4,5} = 10$	$\tau_{1,5} = 50$	$\tau_{2,5} = 60$	$\tau_{3,5} = 60$	$\tau_{4,5} = 50$
$\sigma_{x,y}$				$\zeta_{x,y}$				$\theta_{x,y}$			
$\sigma_{1,2} = 100$				$\zeta_{1,2} = 100$				$\theta_{1,2} = 100$			
$\sigma_{1,3} = 100$	$\sigma_{2,3} = 100$			$\zeta_{1,3} = 100$	$\zeta_{2,3} = 100$			$\theta_{1,3} = 100$	$\theta_{2,3} = 100$		
$\sigma_{1,4} = 100$	$\sigma_{2,4} = 100$	$\sigma_{3,4} = 100$		$\zeta_{1,4} = 100$	$\zeta_{2,4} = 100$	$\zeta_{3,4} = 100$		$\theta_{1,4} = 100$	$\theta_{2,4} = 100$	$\theta_{3,4} = 100$	
$\sigma_{1,5} = 22$	$\sigma_{2,5} = 22$	$\sigma_{3,5} = 22$	$\sigma_{4,5} = 22$	$\zeta_{1,5} = 10$	$\zeta_{2,5} = 10$	$\zeta_{3,5} = 10$	$\zeta_{4,5} = 10$	$\theta_{1,5} = 25$	$\theta_{2,5} = 25$	$\theta_{3,5} = 25$	$\theta_{4,5} = 25$

searching time to find a proper parking in the university. Also, it was intended to raise the satisfaction from this service among staff and students.

In the near future, SBUK can develop a complete web-based application based on the proposed methodology in this paper. In this application first, applicants must register their specifications and demand for a specific parking lot. Then, after gathering all parking requests for a specific day, the ILP model is run and assignments will be announced.

However, the proposed model for parking assignment is highly dependent on exact information about different

Table 11: Frequency distribution of staff in different parking lots.

	Z_1		Z_2		Z_3		Z_4		Z_5		Z_6		Z_7		Z_8		Z_9	
	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	10	$k=1$	0	$k=1$	0
	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	10	$k=2$	0	$k=2$	0
S_1	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	10	$k=3$	0	$k=3$	0
	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	6	$k=4$	0	$k=4$	0
	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	8	$k=5$	0	$k=5$	0
	$k=1$	12	$k=1$	4	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0
	$k=2$	12	$k=2$	4	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0
S_2	$k=3$	12	$k=3$	4	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0
	$k=4$	9	$k=4$	4	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0
	$k=5$	9	$k=5$	2	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0
	$k=1$	8	$k=1$	8	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0
	$k=2$	13	$k=2$	8	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0
S_3	$k=3$	13	$k=3$	7	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0
	$k=4$	9	$k=4$	5	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0
	$k=5$	8	$k=5$	3	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0
	$k=1$	10	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0
	$k=2$	12	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0
S_4	$k=3$	12	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0
	$k=4$	8	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0
	$k=5$	8	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0
									...									
	$k=1$	0	$k=1$	0	$k=1$	2	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0	$k=1$	0
	$k=2$	0	$k=2$	0	$k=2$	3	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0	$k=2$	0
S_{16}	$k=3$	0	$k=3$	0	$k=3$	3	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0	$k=3$	0
	$k=4$	0	$k=4$	0	$k=4$	3	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0	$k=4$	0
	$k=5$	0	$k=5$	0	$k=5$	3	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0	$k=5$	0

Table 12: Parking cost for each time interval.

Time interval	Parking cost (cents)
1	15
2	12
3	8
4	5
5	3

parameters as described in Tables 10 to 13. Especially, as it was relied on stated preferences for students, the reliability of the data must be verified in the real world. However, this issue can be remedied simply by running the system and receiving feedbacks after several weeks. In this manner, more reliable and precise data about different parameters can be achieved. Nevertheless, this challenge does not disturb the overall structure of the ILP model and the proposed idea for parking allocation.

Based on a comparison of the paper results with previous researches, which have been reviewed in the introduction, we can state that the following:

(i) Parking management is an essential topic for urban areas, and we need to involve ITS in this field for more efficiency. However, in the status, more endeavors are needed to promote such systems from different aspects and for different scenarios. The proposed method in this paper can be helpful as a step toward this purpose.

(ii) Most of the previous studies, which relate to university parking management, deal with pricing and its impact on discouraging students from using passenger cars and encouraging them to use sustainable transportation systems. There are parking spaces inside the university at each time interval that can be used for accommodating students' cars. However, it is necessary to consider priorities between students of different education levels in parking assignments. However, in our model, less attention has been devoted to parking pricing and just fixed costs have been proposed for each time interval. We can use dynamic pricing as what has been suggested in the previous studies in the FIS model for students.

(iii) This paper provides a platform for the intelligent parking guidance in the universities. Previously, less has been devoted to parking guidance for the members of a unique organization. For example, Shin et al. [25] studied on dynamic information-based parking guidance for megacities. In their paper, the authors did not allocate parking spaces to users and just tried to provide information about available parking spaces, parking costs, and parking usage history [25]. The present study can be considered in the category of intelligent parking guidance, and it suggests a specific parking lot for each applicant (if available) in the universities to reduce wandering time and traffic congestion and increase their satisfaction.

Table 13: Parking demand on Saturdays (staff and students).

Division	Students		Staff		Division	Students		Staff		Division	Students		Staff	
	$K = 1$	103	$K = 1$	10		$K = 1$	59	$K = 1$	16		$K = 1$	57	$K = 1$	16
	$K = 2$	108	$K = 2$	10		$K = 2$	51	$K = 2$	16		$K = 2$	60	$K = 2$	21
S_1	$K = 3$	68	$K = 3$	10	S_2	$K = 3$	40	$K = 3$	16	S_3	$K = 3$	35	$K = 3$	20
	$K = 4$	49	$K = 4$	6		$K = 4$	30	$K = 4$	13		$K = 4$	30	$K = 4$	14
	$K = 5$	40	$K = 5$	8		$K = 5$	30	$K = 5$	11		$K = 5$	30	$K = 5$	11
	$K = 1$	62	$K = 1$	10		$K = 1$	77	$K = 1$	10		$K = 1$	67	$K = 1$	15
	$K = 2$	47	$K = 2$	12		$K = 2$	75	$K = 2$	10		$K = 2$	57	$K = 2$	15
S_4	$K = 3$	30	$K = 3$	12	S_5	$K = 3$	40	$K = 3$	6	S_6	$K = 3$	40	$K = 3$	15
	$K = 4$	30	$K = 4$	8		$K = 4$	30	$K = 4$	4		$K = 4$	40	$K = 4$	8
	$K = 5$	30	$K = 5$	8		$K = 5$	30	$K = 5$	4		$K = 5$	30	$K = 5$	8
	$K = 1$	80	$K = 1$	18		$K = 1$	96	$K = 1$	8		$K = 1$	89	$K = 1$	4
	$K = 2$	76	$K = 2$	18		$K = 2$	63	$K = 2$	10		$K = 2$	69	$K = 2$	4
S_7	$K = 3$	50	$K = 3$	18	S_8	$K = 3$	40	$K = 3$	8	S_9	$K = 3$	40	$K = 3$	4
	$K = 4$	40	$K = 4$	16		$K = 4$	30	$K = 4$	2		$K = 4$	30	$K = 4$	4
	$K = 5$	30	$K = 5$	12		$K = 5$	30	$K = 5$	2		$K = 5$	30	$K = 5$	4
	$K = 1$	62	$K = 1$	5		$K = 1$	83	$K = 1$	19		$K = 1$	63	$K = 1$	10
	$K = 2$	38	$K = 2$	3		$K = 2$	66	$K = 2$	19		$K = 2$	46	$K = 2$	10
S_{10}	$K = 3$	30	$K = 3$	3	S_{11}	$K = 3$	40	$K = 3$	14	S_{12}	$K = 3$	40	$K = 3$	8
	$K = 4$	30	$K = 4$	3		$K = 4$	40	$K = 4$	8		$K = 4$	30	$K = 4$	8
	$K = 5$	30	$K = 5$	3		$K = 5$	20	$K = 5$	7		$K = 5$	20	$K = 5$	8
	$K = 1$	—	$K = 1$	2		$K = 1$	—	$K = 1$	13		$K = 1$	—	$K = 1$	12
	$K = 2$	—	$K = 2$	2		$K = 2$	—	$K = 2$	13		$K = 2$	—	$K = 2$	12
S_{13}	$K = 3$	—	$K = 3$	2	S_{14}	$K = 3$	—	$K = 3$	13	S_{15}	$K = 3$	—	$K = 3$	12
	$K = 4$	—	$K = 4$	2		$K = 4$	—	$K = 4$	10		$K = 4$	—	$K = 4$	10
	$K = 5$	—	$K = 5$	2		$K = 5$	—	$K = 5$	8		$K = 5$	—	$K = 5$	8
	$K = 1$	—	$K = 1$	2										
	$K = 2$	—	$K = 2$	3										
S_{16}	$K = 3$	—	$K = 3$	3										
	$K = 4$	—	$K = 4$	3										
	$K = 5$	—	$K = 5$	3										

Table 14: Optimization results for Saturdays.

i = 1 k = 1 j = 2 ans = 16	i = 1 k = 2 j = 2 ans = 16	i = 1 k = 3 j = 2 ans = 16	i = 1 k = 4 j = 2 ans = 13	i = 1 k = 5 j = 2 ans = 11	i = 1 k = 5 j = 3 ans = 6	i = 1 k = 5 j = 4 ans = 8	i = 1 k = 1 j = 3 ans = 4	i = 9 k = 2 j = 12 ans = 10
i = 1 k = 2 j = 3 ans = 9	i = 1 k = 3 j = 3 ans = 9	i = 1 k = 3 j = 4 ans = 12	i = 1 k = 3 j = 15 ans = 2	i = 1 k = 1 j = 4 ans = 10	i = 1 k = 2 j = 4 ans = 12	i = 1 k = 4 j = 3 ans = 5	i = 1 k = 4 j = 4 ans = 8	i = 9 k = 3 j = 12 ans = 8
i = 1 k = 5 j = 122 ans = 3	i = 1 k = 5 j = 151 ans = 9	i = 1 k = 5 j = 231 ans = 9	i = 1 k = 5 j = 246 ans = 18	i = 1 k = 5 j = 284 ans = 3	i = 1 k = 5 j = 312 ans = 9	i = 1 k = 5 j = 338 ans = 12	i = 2 k = 1 j = 3 ans = 12	i = 9 k = 4 j = 12 ans = 8
i = 2 k = 1 j = 11 ans = 19	i = 2 k = 2 j = 3 ans = 12	i = 2 k = 2 j = 11 ans = 19	i = 2 k = 3 j = 3 ans = 11	i = 2 k = 3 j = 11 ans = 14	i = 2 k = 4 j = 3 ans = 9	i = 2 k = 4 j = 11 ans = 8	i = 2 k = 4 j = 14 ans = 2	i = 9 k = 5 j = 12 ans = 8
i = 2 k = 5 j = 3 ans = 5	i = 2 k = 5 j = 11 ans = 7	i = 2 k = 5 j = 172 ans = 18	i = 2 k = 5 j = 203 ans = 3	i = 2 k = 5 j = 743 ans = 4	i = 2 k = 5 j = 851 ans = 2	i = 2 k = 5 j = 874 ans = 6	i = 2 k = 5 j = 894 ans = 12	i = 9 k = 5 j = 489 ans = 14
i = 3 k = 1 j = 5 ans = 10	i = 3 k = 1 j = 6 ans = 15	i = 3 k = 1 j = 16 ans = 2	i = 3 k = 1 j = 926 ans = 1	i = 3 k = 2 j = 5 ans = 10	i = 3 k = 2 j = 6 ans = 15	i = 3 k = 2 j = 16 ans = 3	i = 3 k = 3 j = 5 ans = 6	i = 9 k = 5 j = 608 ans = 3

Table 14: Continued.

i = 3 k = 3 j = 6 ans = 15	i = 3 k = 3 j = 16 ans = 3	i = 3 k = 4 j = 5 ans = 4	i = 3 k = 4 j = 6 ans = 8	i = 3 k = 4 j = 16 ans = 3	i = 3 k = 5 j = 5 ans = 4	i = 3 k = 5 j = 6 ans = 8	i = 3 k = 5 j = 16 ans = 3	i = 9 k = 5 j = 630 ans = 9
i = 3 k = 5 j = 327 ans = 6	i = 3 k = 5 j = 365 ans = 3	i = 3 k = 5 j = 388 ans = 9	i = 3 k = 5 j = 415 ans = 18	i = 3 k = 5 j = 469 ans = 4	i = 3 k = 5 j = 955 ans = 6	i = 3 k = 5 j = 975 ans = 12	i = 4 k = 1 j = 7 ans = 18	i = 9 k = 5 j = 658 ans = 1
i = 4 k = 1 j = 8 ans = 8	i = 4 k = 1 j = 14 ans = 3	i = 4 k = 1 j = 599 ans = 2	i = 4 k = 1 j = 659 ans = 2	i = 4 k = 2 j = 7 ans = 18	i = 4 k = 2 j = 8 ans = 10	i = 4 k = 2 j = 14 ans = 3	i = 4 k = 3 j = 7 ans = 18	i = 9 k = 5 j = 909 ans = 2
i = 4 k = 3 j = 8 ans = 8	i = 4 k = 3 j = 14 ans = 3	i = 4 k = 4 j = 7 ans = 14	i = 4 k = 4 j = 8 ans = 2	i = 4 k = 5 j = 7 ans = 10	i = 4 k = 5 j = 8 ans = 2	i = 4 k = 5 j = 64 ans = 11	i = 4 k = 5 j = 84 ans = 11	
i = 4 k = 5 j = 651 ans = 17	i = 4 k = 5 j = 689 ans = 3	i = 4 k = 5 j = 718 ans = 3	i = 4 k = 5 j = 745 ans = 14	i = 5 k = 1 j = 13 ans = 2	i = 5 k = 1 j = 950 ans = 2	i = 5 k = 2 j = 13 ans = 2	i = 5 k = 3 j = 13 ans = 2	
i = 5 k = 4 j = 13 ans = 2	i = 5 k = 5 j = 13 ans = 2	i = 5 k = 5 j = 446 ans = 3	i = 5 k = 5 j = 474 ans = 5	i = 5 k = 5 j = 502 ans = 4	i = 6 k = 1 j = 9 ans = 4	i = 6 k = 1 j = 10 ans = 5	i = 6 k = 2 j = 9 ans = 4	
i = 6 k = 2 j = 10 ans = 3	i = 6 k = 3 j = 9 ans = 4	i = 6 k = 3 j = 10 ans = 3	i = 6 k = 4 j = 9 ans = 4	i = 6 k = 4 j = 10 ans = 3	i = 6 k = 5 j = 9 ans = 4	i = 6 k = 5 j = 10 ans = 3	i = 6 k = 5 j = 717 ans = 6	
i = 7 k = 1 j = 1 ans = 10	i = 7 k = 1 j = 15 ans = 12	i = 7 k = 2 j = 1 ans = 10	i = 7 k = 2 j = 15 ans = 12	i = 7 k = 3 j = 1 ans = 10	i = 7 k = 3 j = 15 ans = 10	i = 7 k = 4 j = 1 ans = 6	i = 7 k = 4 j = 15 ans = 10	
i = 7 k = 5 j = 1 ans = 8	i = 7 k = 5 j = 15 ans = 8	i = 7 k = 5 j = 41 ans = 4	i = 7 k = 5 j = 64 ans = 1	i = 7 k = 5 j = 97 ans = 13	i = 7 k = 5 j = 527 ans = 2	i = 7 k = 5 j = 550 ans = 8	i = 7 k = 5 j = 577 ans = 18	
i = 8 k = 1 j = 14 ans = 10	i = 8 k = 2 j = 14 ans = 10	i = 8 k = 3 j = 14 ans = 10	i = 8 k = 4 j = 7 ans = 2	i = 8 k = 4 j = 14 ans = 8	i = 8 k = 5 j = 7 ans = 2	i = 8 k = 5 j = 14 ans = 8	i = 8 k = 5 j = 527 ans = 1	
i = 8 k = 5 j = 549 ans = 1	i = 8 k = 5 j = 748 ans = 6	i = 8 k = 5 j = 792 ans = 18	i = 9 k = 1 j = 12 ans = 10	i = 9 k = 1 j = 629 ans = 3	i = 9 k = 1 j = 663 ans = 4	i = 9 k = 1 j = 950 ans = 1	i = 9 k = 1 j = 980 ans = 6	

Table 15: Wandering time and satisfaction of students and staff.

	Wandering time (minute)				Satisfaction			
	Staff	B.Sc. students	M.Sc. students	Ph.D. students	Staff	B.Sc. students	M.Sc. students	Ph.D. students
Current status	0.32	3.4	3.1	2.8	Medium	Low	Very low	Very low
Proposed scheme	0	2.9	2.3	1.8	Very high	Medium	Medium	High
Mean difference	0.32 (sig = 0.05)	0.5 (sig = 0.05)	0.8 (sig = 0.1)	1 (sig = 0.05)	1.8 (sig = 0.05)	0.7 (sig = 0.1)	2.1 (sig = 0.05)	3.2 (sig = 0.05)

(iv) For students, the demand for parking spaces might be greater than the supply in some intervals. In the current status, those who have requested sooner for a parking lot have more priority and the application regards this priority when devoting parking lots. However, this can be another limitation of this application, and further works can be done to promote it.

At last, it can be declared that, although the proposed method has been applied for a specific case study (SBUK), it can be used for other organizations. For each organization, the right-hand sides and model coefficients will be changed in the ILP model. In addition, the input ranges and rules might change in the FIS model.

This paper also has some limitations such as considering constant parking costs, disregarding withdrawals for parking request, relying on stated preferences of students, considering constant shares for each education level, and disregarding the differences between employees, professors, and workers, among others.

For future studies, based on these limitations, dynamic pricing can be used instead. In addition, adaptive neuro-fuzzy inference system (ANFIS) can be employed instead of FIS, by providing a complete database from students' behavior. More variations can be considered in the ILP in order to have a dynamic and real-time model. However, it is necessary to think about the platform, which can provide updated information for the users.

6. Conclusion

Nowadays, many universities around the world suffer from a lack of campus parking capacity. Many of these universities are seeking solutions for parking and congestion difficulties in their campus area. To tackle this problem, it is necessary to regard several considerations to assign parking spaces to intercampus users, based on their different characteristics. As a result, the present paper tries to provide a procedure to develop a web-based application for parking management in SBUK. For this purpose, an ILP model was used to optimize the parking lots' assignments. This model sought to determine the number of vehicles from different divisions, which can park in the different parking lots at different time intervals. The objective function of the ILP model is to increase the probability of parking at each location. Despite having enough space to accommodate a group of students inside the university, they are not currently allowed to bring their car inside the campus. Therefore, the parking probabilities for the staff are determined based on their preferences, obtained by field data collection. Afterward, using the data collected based on the questionnaire, a FIS model was used to calculate the parking probabilities for the students. The ILP constraints at each time interval relate to different factors such as the capacity of each parking lot, the preferences of staff to park in a specific parking lot, the fulfilment of all staff parking demands, the students' demand for parking, and the education level of students. Comparing the results for a specific day of the week with the current status, it can be declared that the model can be effective for better exploitation of parking spaces inside the SBUK. In the proposed model, institutional rankings and priorities of different groups were considered, and it was tried to help drivers to park in the preferred parking lot. Using this approach, the wandering time to find an appropriate parking and dissatisfaction from parking management would be decreased.

Data Availability

The data used to support this study can be made available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

Appendix I: questions for staff. Appendix II: questions for students. (*Supplementary Materials*)

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