DESIGN AND ANALYSIS OF INFORMATION-BASED CAR PARKING SYSTEM

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ABSTRACT

This paper discusses the design and simulation analysis of an information-based car parking (INFOPARK) system. The INFOPARK system continuously monitors all parking spaces in the parking facility and keeps record of the available spaces. A car entering the parking facility is then informed of the location of one of these available parking spaces so that it can proceed directly to the assigned location. The INFOPARK system eliminates the need to search for a parking space, increases the efficiency of the parking service, and improves the traffic condition inside the facility.

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INTRODUCTION

Recently, car parking service has emerged as a new type of prospective business in Bangkok, the capital to Thailand. This is due to the fact that a lack of parking spaces in Bangkok is becoming another major problem of the city; perhaps is only second to the traffic problem. Drivers may have to park their cars several blocks away and then walk to their destination in order to save time and to avoid frustration. When the traffic problem has grown and reached an unacceptable level, parking on the streets during business hours has been prohibited in order to allow better traffic flow. As a result, business in downtown area have lost a significant number of customers due to their inability to provide sufficient car parking accommodation. Nevertheless, relocating the business to the suburban area where parking spaces are relatively more available may not be an attractive alternative since customer traffic is typically less in the suburban than in the urban or downtown areas. To cope with the parking problem, a number of indoor parking garages have been built to provide the parking service.

Major department stores and shopping malls usually have their indoor parking garages and provide parking spaces for their customers either free of charge or at nominal fee depending on parking duration while charging an expensive parking fee for others. In the downtown areas, however, pay-per-hour commercial parking garages have been benefited from the scarce of parking spaces. This business enjoys the advantages of low maintenance cost, low labor cost (only one or two parking attendants may be needed), and guaranteed customers.

Although two types of parking garages (i.e., outdoor and indoor) are commonly seen, the indoor type is more space efficient since the garage can be a multi-story building which will increase the utilization rate as well. Typical indoor parking garages exist in two types according to its proximity to the offices/stores: (1) in the same building, and (2) as a separate building. If the indoor parking garage is in the same building as the business offices/stores, the facility may be provided on the same floors (so that customers can easily access their destination) or on separate floors (for safety and ease of administration). For the garage located in a separate building, there must be walkways connecting between the garage and the commercial building. These walkways may be found on every floor or on certain designated floors.

For all types of car parking facility, the quality and efficiency of service is determined by the amount of time that a customer spends in order to find a parking space. It is obvious that if the parking system has not been properly designed or the parking proces has not been efficiently managed, customers may have to spend unnecessary time searching for available parking spaces.

This paper discusses a design of an information-based car parking system which can help customers locate available parking spaces quickly. Initially, a conceptual design is presented. The rule used in assigning parking spaces is also explained. Finally, a comparison

between the conventional and information-based car parking systems is provided through a simulation analysis.

INFORMATION-BASED CAR PARKING SYSTEM

The information-based car parking (INFOPARK) system is a computer controlled and continuously monitored parking system which will, upon the entrance of a customer, search for the best available parking space and then assign that space to the customer. At the entrance of the parking facility, the customer is given essential information such as whether or not there is an available parking space in the area and the location of the space as designated by the floor number, aisle number, and space number. From the given information, the customer can then enter the facility and proceed to the assigned space without having to drive around trying to find a parking space. In the case that there is no avilable parking space at the time of entry, the customer will be informed so that he/she can leave the premises and go elsewhere to find the parking space.

Individual parking spaces will have sensors which will be connected to the central computer. These sensors help monitor the availability of parking spaces. The assignment of parking spaces to customers will not follow the first available, first assigned principle. On the other hand, the INFOPARK system uses a priority rule in assigning parking spaces. All spaces will be ranked according to the amount of time required to drive from the entrance of the facility to the parking space until completely parking the car. The space having the shortest time will be assigned first. This assignment is based on the fact that nearly all customers want to find the parking space which is the closest to their destination. This explains while some customers do not park their cars at the first seen parking space, but choose to drive around hoping to find a better space to park. Mathematically, the amount of time used in ranking the assignment preference is

$$T = \sum_i T_i \qquad (1)$$

where: T = Total amount of time required to complete the parking process

T_i = Elemental time of the ith activity involved in the parking process

In order to demonstrate the operation of the INFOPARK system and to verify is superiority to the conventional car parking system, an example of the parking facility which is very common in Bangkok, Thailand, is provided. The analysis and performance comparison are accomplished using Taylor II simulator.

SYSTEM MODELING AND SIMULATION

The chosen facility is an indoor parking garage which is built as a separate building from the offices/stores/shopping center. The facility is a two-story building with separate entrance and exit. There is only one walkway located on the first level that connects between the parking garage and the commercial building. Customers who park their cars on the second level must walk down the stairway to go the walkway.

Entering cars are permitted to go the second level without having to drive through the first level. Similarly, departing cars from the second level are also permitted to bypass the first level during the process of leaving the facility. Once entering any parking level, cars must follow a directed one-way driveway which will lead them through the entire floor. After the floor has been unsuccessfully searched for a parking space, customers may either proceed to the next higher lever, return to the lower parking level, or repeat the search process on the same floor. There are 18 parking spaces in this parking facility, 9 spaces on the first level and the other 9 spaces on the second level. Figure 1 shows layouts of the first and second parking levels and driving directions.

Assumptions:

1. The customer drives at a speed of 2.5 m/s.
2. The customer walks at a speed of 1.0 m/s.
3. It takes the customer 15 s to walk down the stairs.
4. Driving from the entrance to the parking space No.1 & 2 takes 3 s.
5. Driving from the parking space No.1 & 2 to No.3 and from No.3 to No.4 & 5 takes 1.2 s equally.
6. Driving from the parking space No.4 & 5 to No.6 & 7 and from No.8 & 9 to No.1 & 2 takes 7 s equally.
7. Driving from the parking space No.6 & 7 to No.8 & 9 takes 2.4 s.
8. Driving from the parking space No.8 & 9 to the exit to the second level takes 3 s.
9. Driving from the exit to the second level to the entrance to the second level and from the exit from the second level to the entrance from the second level (on the first level) takes 12 s equally.

Since the layout of the second level is identical to that of the first level, all assumptions will thus be the same.

1. Conventional Parking System

For the conventional parking system, customers must find a parking space by themselves without any assistance. It is assumed that customers always attempt to park their cars as close as possible to the walkway. Therefore, we can estabilished the following preference lists of parking space No. for the first and second parking level.

Parking Level 1: 7, 6, 9, 8, 2, 1, 3, 4, 5

Parking Level 2: 16, 15, 18, 17, 11, 10, 12, 13, 14

These preference lists are developed based on two criteria: (1) the distance between the parking space and the walkway, and (2) the arrival sequence (if there is a tie in the first criterion).

Firstly, the customer will always enter the first parking level and search for the best parking space using the preference list given above. In other words, if there are no available parking spaces on the first level, the customer must drive around the parking area twice before leaving for the second parking level. Once entering the second level, the customer will once again follow the preference list shown above in order to find the best parking space on that level. Therefore, the customer may have to drive around the driveway twice. If there are no parking spaces

on the second level, the customer will return to the first level for another attempt to find the parking space. If there still are no parking spaces available, the customer will drive around once and then leave the facility. It can be seen that at maximum the unsatisfied customer has to drive around inside five times before leaving the parking facility, three times on the first level and two times on the second level.

2. Informational-Based Car Parking (INFOPARK) System

The INFOPARK system simplifies the search process by continuously monitoring all parking spaces to determine which are available and which are not. For those spaces that are available, the system also determines the order of assignment using the above mentioned priority rule. The assignment order will be updated every time that another parking space becomes available. The customer entering parking facility will always be assigned the current best parking space to guarantee customer satisfaction. If there are no parking spaces available at the time the customer arrives, the customer will not be allowed to enter the parking facility and must leave the facility as an unsatisfied customer.

In this example, the customer will enter the parking facility, drive to the parking space, park the car, and then walk to walkway which is connected to the adjacent building (or the customer's destination). The entire process is called the "drive-park-walk" or the DPW process. The INFOPARK system intends to assign the parking space with the current minimum DPW time. We also assume that the customer is more interested in finding the parking space which is as close as possible to the walkway than finding the space that will enable one to quickly leave the facility when the service has been completed.

Let $T1_i$ = Driving time from the entrance of the facility to the i^{th} parking space

P = Amount of time taken to park the car (assumed to be 15 s)

$T2_i$ = Walking time from the i^{th} parking space to the walkway (including the time spent in walking down the stairs from the second level, if applied)

T_i = The DPW time of the i^{th} parking space

We then have

$$T_i = T1_i + P + T2_i \qquad (2)$$

Table 1 shows the DPW times of all parking spaces, their elemental times, and ranks.

The time between customer arrivals is assumed to follow an exponential distribution [1]. To make the system more realistic, it is assumed that this parking facility operates from 9:30 a.m. to 10:30 p.m. (However, no customers will be allowed to enter the parking facility after 8:30 p.m.) This is to accommodate the operation time of the shopping center which is open at 10:00 a.m. and closed at 9:00 p.m. Furthermore, the operation duration is divided into five period (see Table 2). The mean times between customer arrivals of these five periods differ and are given in Table 2 as well. The service time also follows an exponential distribution with a mean of 1 hour (3,600 s). The simulation time is for 30 days.

RESULTS AND CONCLUSION

The performance measures used in the comparison between the conventional and information-based car parking systems are:

1. Average DPW time (s)
2. Average utilization (%) of the first parking level
3. Average utilization (%) of the second parking level
4. Average number of satisfied customers
5. Average number of unsatisfied customers.

Table 3 shows the performance measures of both car parking systems. The data shown represent the average values from 30 days.

A statistical comparison on the DPW times from both car parking systems shows that the difference is signficant at $\alpha = 0.05$ [2]. On the other hand, the differences between other performance measures are found to be insignificant.

It can be concluded that the information-based car parking system is superior to the conventional one since the average DPW time of the former is significantly less than that of the latter. This result has initially been anticipated since customers do not have to spend a large portion of time driving around the parking facility in order to find the parking space. Additionally, the INFOPARK system uses the priority rule in assigning the best available parking space to each customer which will consequently help minimize the DPW time.

Although the simulation software (Taylor II Simulator) used in this study is flexible and unlimited in the model size, the software does not enable the investigators to write a simulation program for this car parking system. By viewing the car parking facility as a factory floor, parking spaces as machining workstations, and cars as automated guided vehicles (AGVs) that deliver workpieces to the machines, it is possible to simulate the car parking system using Taylor II. However, building such systems is laborious and inflexible in designing the system operation. These limitations thus explain why the car parking system under investigation in this paper is designed to be a two-story building and there are only nine parking spaces on each floor. Yet, it should still be noted the even with a small system, the INFOPARK system show a superior performance to that of the conventional one. It is anticipated that when the level of system complexity increases, so does the superiority in the performance of the INFOPARK system. A simulation program is being written using ARENA to study the performance of the INFOPARK system with larger system size and higher level of complexity.

In several countries such as U.S.A. and Japan, some car parking systems were developed to cope with this problem. Valet parking is the system popularly used in U.S.A. especially in big cities. Drivers normally drive into the entrance of the parking facility, leave the car and the car key the parking attendant, and receive the claim ticket. The parking attendant will be responsible to park the car at the parking space which may be assigned by following the ascending order of the parking space number. In Japan, a carousel-liked parking facility has been utilized in big

cities. With this system, drivers can drive into the parking platform, lock the car, and take the claim ticket. The carousel will automatically move the car to the parking space. The directions of movement mainly depend on the design of the parking facility. This system not only saves space but also time. Nevertheless, the design and building cost can be expensive which may make this system unpopular. The INFOPARK system is intended to be a low cost alternative since it can be adapted to the existing facility. (Additional costs are due to the computerized controller and sensors.)

At present, several factors which may have significant effects on the INFOPARK system performance have been excluded. Entering customers may not always behave in the same manner as that assumed in this paper. Some customers may choose to park at the first available parking space seen on their way. Some may be so pessimistic that they tend to assume that the first parking level should have been full; thus ignoring an attempt to search in the first level and proceeding to the second level immediately. Moreover, some customers may prefer the parking space that enables them to quickly leave the parking facility once the business is completed. This means that there must be a compromise between the "quick park" and the "quick leave" options. It is also possible to view this car parking system as a storage system and apply certain location methods such as dedicated location policy, randomized location policy, and class-based dedicated location policy in managing the car parking system [3].

REFERENCES

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TABLE 1

DPW Times of the Parking Spaces and Their Ranks

Parking Space	Amount of Time Spent in			Total DPW Time	Rank
	Driving	Parking	Walking		
1	3.0	15	26.5	44.5	8
2	3.0	15	18.5	36.5	3
3	4.2	15	23.5	42.7	6
4	5.4	15	33.5	38.9	4
5	5.4	15	41.5	46.9	9
6	12.4	15	28.5	40.9	5
7	12.4	15	20.5	32.9	1
8	14.8	15	28.5	43.3	7
9	14.8	15	20.5	35.3	2
10	22.0	15	56.5	78.5	17
11	22.0	15	48.5	70.5	12
12	23.2	15	53.5	76.7	15
13	24.4	15	33.5	72.9	13
14	24.4	15	41.5	80.9	18
15	31.4	15	28.5	74.9	14
16	31.4	15	20.5	66.9	10
17	33.8	15	28.5	77.3	16
18	33.8	15	20.5	69.3	11

TABLE 2

Time Periods and Their Probability Distributions

Time Period	Business	Time between Customer Arrivals
09:30 - 11:30 a.m.	Slow	Exponential, mean = 400 s
11:30 - 12:30 a.m.	Busy	Exponential, mean = 120 s
12:30 - 03:30 p.m.	Moderate	Exponential, mean = 240 s
03:30 - 06:30 p.m.	Busy	Exponential, mean = 120 s
06:30 - 08:30 p.m.	Slow	Exponential, mean = 400 s

TABLE 3

Comparisons of Performance Measures of Car Parking Systems

Performance Measure	Car Parking System		Difference
	Conventional	Information-Based	
DPW time	84.03	53.57	Significant
Utilization of first level	79.17	78.93	Insignificant
Utilization of second level	54.94	56.23	Insignificant
Satisfied customers	152.70	152.97	Insignificant
Unsatisfied customers	45.70	45.43	Insignificant

LIST OF FIGURES

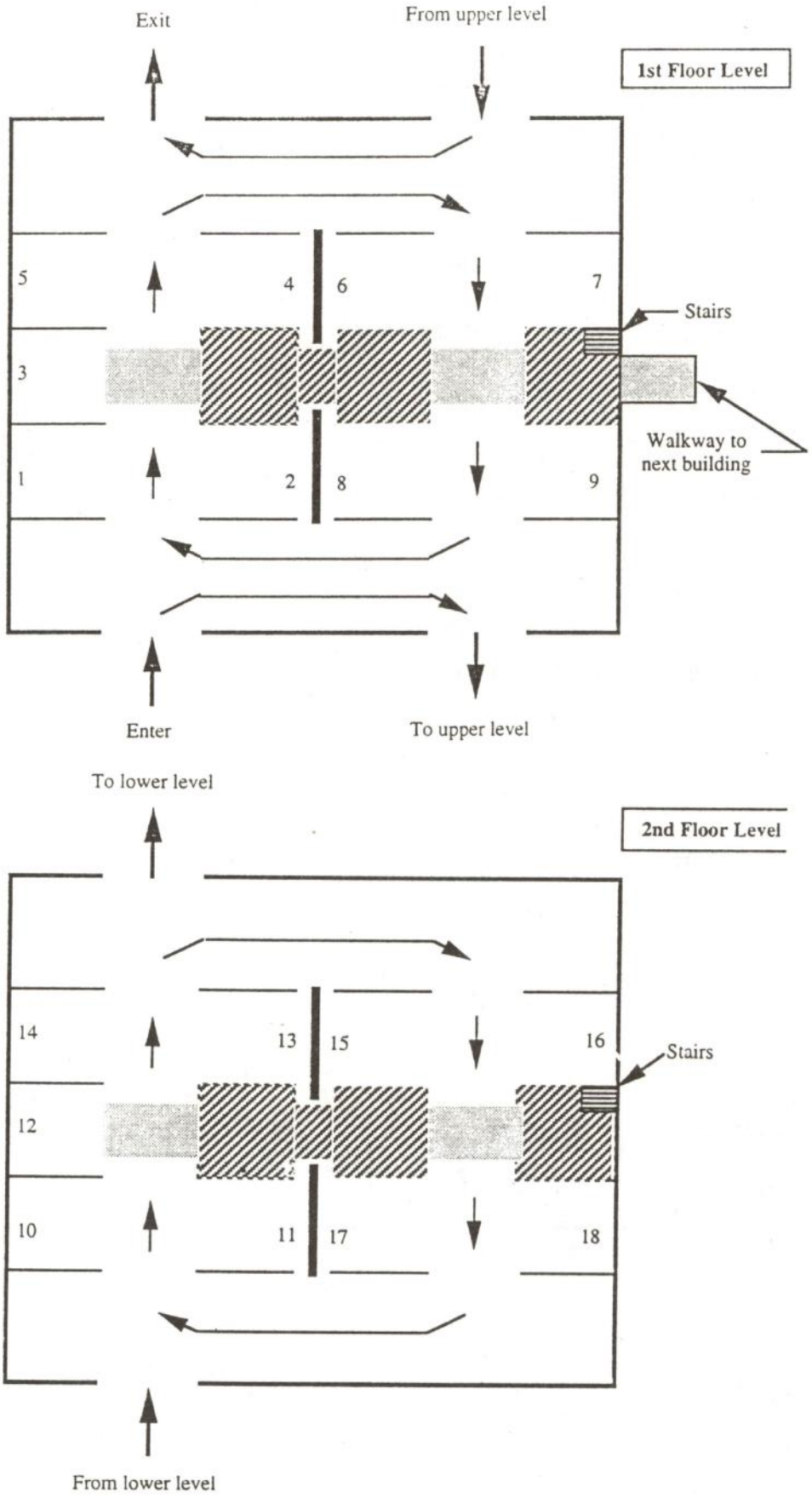

Figure 1: Floor layouts of the first and second parking levels