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A SIMULATION APPROACH FOR ANALYZING PARKING SPACE AVAILABILITY AT A MAJOR UNIVERSITY

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ABSTRACT

Simulation is used to evaluate parking space availability for a current layout and for future design options at Miami University. By using simulation, an alternative design that increased the average number of parked cars and decreased the number of balked cars was derived. This paper describes the models developed and provides details on the analysis.

1 INTRODUCTION

Miami University implemented new parking rules and regulations for the 1995-1996 school year. Colored parking tags are assigned according to your association with the university. Red sticker tags are for faculty and staff members. Green sticker tags are for graduate assistants. Blue sticker tags are for undergraduates and graduates who do not have an assistantship at Miami. Red sticker cars have the highest priority followed by green and blue sticker cars. The new parking rules were not implemented in a way that would maximize parking availability for the majority of the Miami University community (Harris 1996). In order to determine the best number of required parking spaces for each color tag, simulation was chosen as the method of analysis because it easily lends itself to incorporating the complexity of the relationships between system components (Pritsker 1986).

A reflective sample of Miami campus' parking spaces was modeled. The experimental unit selected was Cook Field, which is one of the major parking units at the university. The statistics of interest in this study are: the number of cars that exited the lot after not being able to find an open parking space (balked cars) in particular for red sticker cars during the morning hours, and the average number of cars that are actually "parked" in Cook Field.

2 MODEL DESCRIPTION

A schematic of the current parking layout for Cook field is shown in Figure 1. The east side of Cook Field is restricted to red sticker cars. The west side is for red and green sticker cars. The north and south side is open to all sticker colors.

Figure 1: Schematic of Cook Field

Prior to creating alternative parking designs for evaluation, the following parking rule assumptions were made: red sticker cars will try to park in the lot the prioritized order "red only" area, red & green area, then red, green, & blue area; green sticker cars will try to park in the order: red & green area, then red, green, & blue area; and blue sticker color cars try to immediately park in the area for all sticker colors. Moreover, we assumed that a car waits for a parking space if and only if no other car of the same sticker color is waiting for a space. Otherwise, the car will try to park in the next prioritized area. In the event that other cars are waiting to park in

each area, the car will exit the lot. This modeling logic is represented in Figure 2.

For each of the alternatives created, the assumptions made for each model of the alternatives are as follows:

- The model represents a parking process from 7 a.m. to 4 p.m.
- Cars entering the parking lot follow a nonhomogeneous Poisson process with a mean arrival rate depending on the time of day. Interarrival times are commonly modeled as Poisson random variables (Banks et. al. 1996).
- Red and green sticker cars parking time is from 2 to 9 hrs, with a higher probability of parking for a longer period of time than a shorter period of time.
- Blue sticker cars parking time is from 2 to 4 hours.
- Only one car of each sticker color type can wait for (circling the lot) an open parking space.

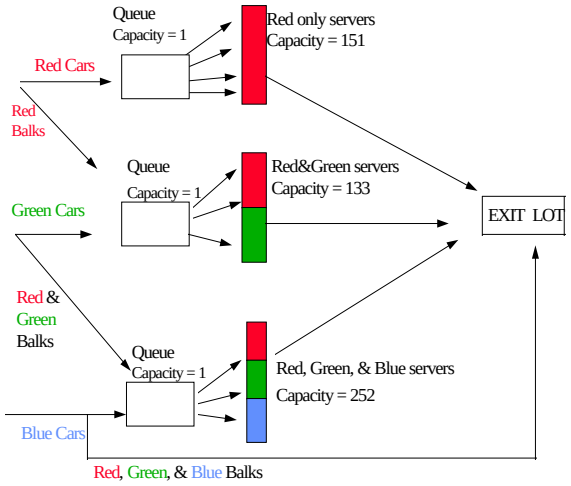

Figure 2: Logic of Modeling for Current Design

Based on the above assumptions, the following parking times were used:

Sticker Color	Time of Day	Parking Time
Red	7 a.m. to noon	Tri(2hrs, 8hrs, 9hrs)
Red	noon to 3 p.m.	Tri(2hrs, 3hrs, 4hrs)
Red	3 p.m. to 4 p.m.	1 hour
Green	7 a.m. to noon	Tri(2hrs, 8hrs, 8hrs)
Green	noon to 4 p.m.	Tri(2hrs, 3hrs, 4hrs)
Blue	7 a.m. to noon	Uniform(2hrs, 4hrs)
Blue	noon to 3 p.m	Uniform(2hrs, 4hrs)
Blue	3 p.m. to 4 p.m.	1 hour

The arrival times of red, green, and blue sticker cars were collected during 3 different time intervals: 8 a.m. to 9 a.m., noon to 1 p.m., and 3 p.m. to 4 p.m.. Data was collected on a Monday since it is considered the busiest parking day of the week. The Chi-Square Goodness of Fit Test verified the assumptions of exponential interarrival times and different interarrival patterns according to the time of day. Below are the arrival patterns used:

Sticker Color	Time of Day	Interarrival Time
Red	7 a.m. to noon	Exp(55.22 seconds)
Red	noon to 3 p.m.	Exp(42.45 seconds)
Red	3 p.m. to 4 p.m.	Exp(58.54 seconds)
Green	7 a.m. to noon	Exp(74.17 seconds)
Green	noon to 4 p.m.	Exp(117.93 seconds)
Blue	7 a.m. to noon	Exp(35.56 seconds)
Blue	noon to 3 p.m.	Exp(59.48 seconds)
Blue	3 p.m. to 4 p.m.	Exp(28.09 seconds)

It was determined that the current parking process as well as alternate parking processes could be represented using queuing models. Each queuing model; whether alone or networked with other queuing models, would be of the form M/G/S/FCFS/S+1/∞. There are no readily available formulas or charts for a queuing model of this type. Consequently, building simulation models of the various parking policies using the common random number technique approached the problem. The simulation language used was SIMAN (Pegden et. al. 1995).

3 EXPERIMENTATION

Tables 1 and 2 show the simulation results for the current design and for possible alternative designs. In the tables C denotes the current configuration, and A1, A2, and A3 denote the three alternative designs respectively. The layouts for the three alternative designs are discussed next.

Table 1. Average Number of Cars Parked in Lot

Design	Total
C	463
A1	425
A2	450
A3	456

Table 2. Average Number of Balked Cars

Color	Time	C	A1	A2	A3
Red	7 a.m. to noon	87	28	134	64
Red	Noon to 3 p.m.	85	143	159	92
Red	3 to 4 p.m.	3	5	9	2
Green	7 a.m. to noon	67	47	49	52
Green	noon to 4 p.m.	44	34	34	43
Blue	7 a.m. to noon	157	360	161	226
Blue	noon to 3 p.m.	108	119	34	122
Blue	3 to 4 p.m.	61	111	66	86

The first alternative was designed to encourage more undergraduates to utilize the Miami Metro bus service. The east and west side of Cook Field are now restricted to red sticker cars. The south side of Cook Field is restricted to Green sticker cars, while the north side of Cook Field is restricted to blue sticker cars. Compared to the current design of Cook Field, there is a significant decrease in parking availability reserved for blue sticker cars. The simulation logic for this design is represented in Figure 3. Each car will try to park only in the area corresponding to their sticker color.

The second alternative divided the 536 parking spaces evenly among the red, green, and blue sticker cars; with one additional space allotted to the red and green area. The idea behind this design was to reduce the number of balks for blue sticker cars. Each car can only park in a space that corresponds to its sticker color. Note, the simulation logic for this alternative is identical to Alternative #1 (A1) except that the number of parking spaces for each color is different.

In the third alternative, the parking spaces immediately surrounding the Physical Facilities building is restricted to red sticker cars, with the remainder of the east and west side of Cook Field open to red and green sticker cars. The north and south side of Cook Field is open to all sticker colors. The idea behind this design was to assign red parking spaces closer to where a majority of the staff worked (e.g. Physical Facilities). Because Physical Facilities employees begin their workday at 7:30 a.m., the red spaces surrounding the building will be utilized first. Note, the simulation logic for this alternative is identical to the current layout except that the number of parking spaces for each color is different.

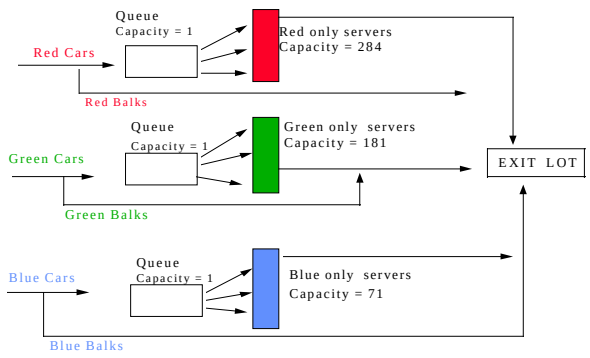

Figure 3: Logic of Modeling Strategy for A1 Design

At first in comparing the designs, the current configuration and Alternative #3 (A3) were analyzed for significant differences in performance for they were both models of queuing networks. Conversely, Alternatives #1 and #2 (A2) were studied for significant differences in performance for they were both models of stand-alone queuing systems. Statistics were collected for the number balking of each sticker color type, and the average number of cars of each sticker color parked in the lot.

A scoring system was devised to compare the designs as shown in Table 3. The system was designed to give higher priority to an alternative that has a lower number of cars that balked in particular for red sticker cars during the morning hours, and a higher average number of cars that are parked. If a statistic was significantly different, the statistics score was added to the design's total score. A parking design alternative is preferred if it has a higher score.

Table 3. Scoring System

Statistic	Color	Time	Score
Balk	Red	7 a.m. to noon	7
Balk	Red	noon to 3 p.m.	5
Balk	Red	3 to 4 p.m.	3
Balk	Green	7 a.m. to noon	5
Balk	Green	noon to 4 p.m.	3
Balk	Blue	7 a.m. to noon	3
Balk	Blue	noon to 3 p.m.	2
Balk	Blue	3 to 4 p.m.	1
Avg. Park	-	-	5

Table 4 shows which statistics were significant when comparing C with A3. Alternative #3 (score of 12) is a preferred design in comparison (score of 9) to the current design of Cook Field. The reason for this is the number of balks are lower in the morning for red and green sticker cars; the busiest parking time interval. However, there is an increase in the number of blue sticker cars balking throughout the day. Nonetheless, this "inconvenience" is compensated with the service of the Miami Metro system. That is, undergraduate students that live in the Oxford community or on campus would be encouraged to use the Miami Metro busing service; the primary purpose of the bus service.

Table 4. Significant Statistics: Comparison C & A3

Statistic	Color	Time	Preferred Design
Balk	Red	7 a.m. to noon	A3
Balk	Green	7 a.m. to noon	A3
Balk	Blue	7 a.m. to noon	C
Balk	Blue	3 p.m. to 4 p.m.	C
Avg. Parked	-	-	C

Table 5 contains the significant statistics from the comparison of A1 to A2. These results indicate that A2 (score of 11) and A1 (score of 10) are nearly equal. The reason for this is that A2 has a higher average number of parked cars. However, A1 has significantly less red sticker cars (faculty and staff) balking in the morning, which has the highest priority. It was the opinion of the authors that the "inconvenience" of increased balking of blue sticker cars (fewer parking spaces for undergraduate students) in design A1 can be compensated by the Miami Metro bus service. This qualitative factor resulted in the preference of A1 over A2.

Table 5. Significant Statistics: Comparison: A1 & A2

Statistic	Color	Time	Preferred Design
Balk	Red	7 a.m. to noon	A1
Balk	Red	3 to 4 p.m.	A1
Balk	Blue	7 a.m. to noon	A2
Balk	Blue	noon to 3 p.m.	A2
Balk	Blue	3 to 4 p.m.	A2
Avg. Parked	-	-	A2

The final analysis involved comparing the better of the previous two comparisons, Alternative #1 and Alternative #3. The results from this analysis are contained in Table 6. The statistics show that compared to Alternative #1 (score of 10), Alternative #3 (score of 14) increases the average number of parked cars and has periods where red sticker cars balk significantly less.

Table 6. Significant Statistics: Comparison: A1 & A3

Statistic	Color	Time	Preferred Design
Balk	Red	7 a.m. to noon	A1
Balk	Red	noon to 3 p.m.	A3
Balk	Green	noon to 4 p.m.	A1
Balk	Blue	7 a.m. to noon	A3
Balk	Blue	3 to 4 p.m.	A3
Avg. Parked	-	-	A3

4 CONCLUSIONS AND RECOMENDATIONS

Computer simulation was used successfully to assist in the development of a proposal to better utilize parking space availability at Miami University. Statistical evaluation of the performance of alternative parking design models ascertained that an improvement over the current parking scenario exists. The recommended parking arrangement is: (1) the parking area immediately surrounding the Physical Facilities Building is a "red only" area, (2) the remainder of the east side along with the entire west side of Cook Field is closed only to blue stickered cars, and (3) the north and south side of Cook Field are opened to all sticker colors. Analysis has indicated that implementing these changes will result in a decrease in the number of red stickered cars that balk and an increase in the average number of cars parked in Cook Field.

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