OPTIMIZATION OF RESOURCE DISTRIBUTION IN THE GEORGE MASON UNIVERSITY PARKING SYSTEM

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ABSTRACT

The users of George Mason University's parking system are quickly outgrowing the capacity of the system and are dissatisfied with the quality of the service this system provides, yet George Mason parking services are still in debt from previous expansion projects. Plans are already underway to increase the capacity of the system but not without great financial expense. Our objective is to provide a more effective means of distributing the resources of the parking system at George Mason University that is relatively inexpensive and that will work in conjunction with the existing plans to expand George Mason's parking system.

Our system design consists of a series of policies to be enacted on the George Mason University parking system by 2004. These policies are: providing carpooling incentives, restricting resident students from parking in the most valuable parking spaces, selling reserved spaces via a uniform price sealed bid auction, and differentiating the decal prices into several value groups.

The effect of these policies was modeled using a computer simulation that replicated the acquisition of the system's parking spaces by stakeholders during peak hours. Results showed that the increased derived utility realized by the users of the parking system was minimal but the increased revenue obtained was significant.

PROBLEM STATEMENT

George Mason University (GMU) plans to grow to 30,000 students by 2007 and decrease its teacher to student ratio to 1:14. The effective growth rate between 2002 and 2007 will be approximately 1000 a year. Figure 1 displays the historic and projected student population on the Fairfax campus of George Mason between 1992 and 2014 (Office of IR&R 2001). Clearly, new spaces must be built to meet this growing demand.

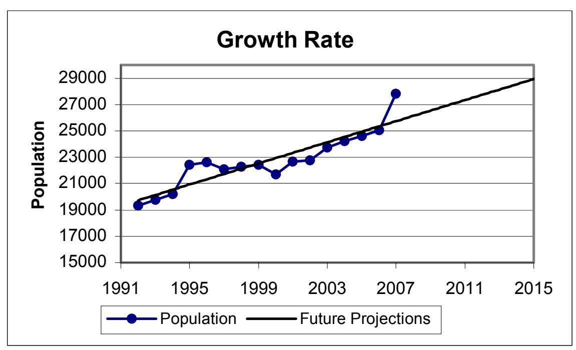

Figure 1. Historic and Projected Student Population on Fairfax Campus.

The George Mason campus, as seen in Figure 2, has limited space to build further lots. A large lot could conceivably be built behind lot K, but parking in this lot would be immensely inconvenient. Any new spaces that would be convenient for the parking system's users must be placed along Patriot Circle, the circular road surrounding the central portion of the campus containing the majority of the buildings, lots B and E, and the parking deck. Since the real estate surrounding Patriot Circle is nearly all occupied, the only real option available for significant expansion of the parking system must be to build parking decks above the existing lots around Patriot Circle such as in Lot B and F.

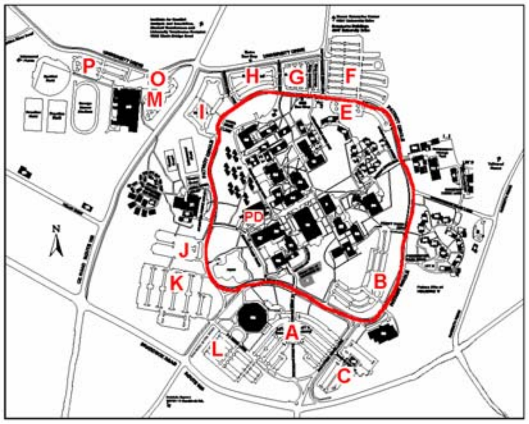

Figure 2. Map of GMU campus in 2002.

The cost of constructing a parking space around $7,000 per space and the maintenance of these spaces approaches $1,000 per space annually; the drastic growth George Mason is expecting will put a tremendous strain on the parking system's finances, especially since the parking system is already in debt from previous expansion projects (OTDE 2001). Figure 3 gives the retained earnings of the GMU parking system since 1998 and the projected retained earnings up to 2004.

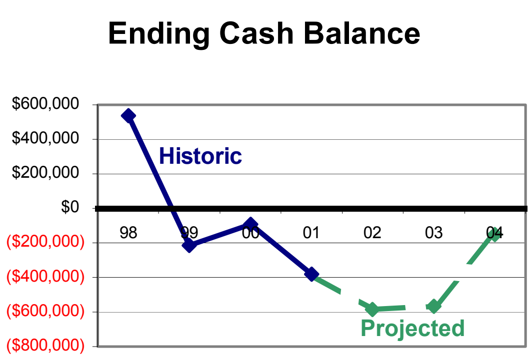

Figure 3. Retained Earnings of System.

Finally, the stakeholders who use the system, the visitors, resident and commuter students, faculty, and staff, do not feel the system effectively fulfills their needs. Any solution to this problem must improve the quality of service of the parking system while taking into account the growing population of the campus and costs to the system.

PERFORMANCE METRICS

The effectiveness of the parking system to fulfill the needs of its various stakeholders was measured using six performance metrics. These performance metrics are

- Time to Destination	- Free Space in Parking Space
- Shelter	- Parking Space Cost
- Safety	- Perceived Fairness

Most of the metrics deal directly with the parking spaces that constitute the parking system, although the perceived fairness of the parking system deals with the system as a whole.

A pilot survey was conducted to understand which performance metrics were of value to the stakeholders and to what degree. This survey provided two types of information regarding each metric. The first set of questions gave a quantitative measurement of the importance of each performance metric valued by the stakeholder relative to each of the other performance metrics. The second set of questions gave a discrete measurement of the utility derived from each metric at different values of the metric. The survey took a selective sample from each of the four stakeholder groups.

Time to Destination

This metric represents the time it takes for a stakeholder to reach his approximate destination on campus from the average campus entrance. It is an attribute of the parking spaces in the parking system and contained two parts, the average driving time required for a stakeholder to reach the sample parking space and the average walking time required for a stakeholder to reach any of four destination zones from the sample parking space. The average walking speed found to be 2 miles an hour and the average driving speed was found to be 10 miles an hour.

Figure 4 gives a graphical representation of the parking lots in GMU, Fairfax campus versus the average time to destination (average entrance to center of campus). It is clearly shown that the most parking lots have an average time of 15 to 20 minutes.

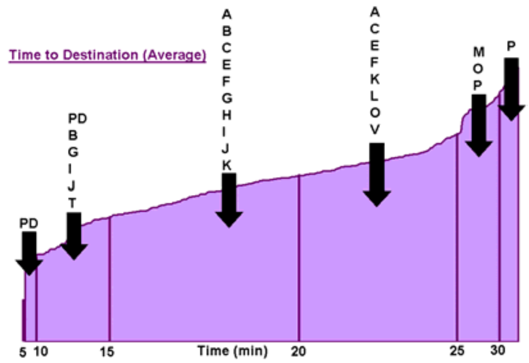

Figure 4. Time to Destination (per lot).

Shelter

Shelter is another attribute of the parking spaces in the parking system at GMU. The shelter metric is a discrete qualitative measure of the shelter covering a space. Parking space ratings are as follows:

0	No Shelter
1	Great Deal of Tree Coverage
2	Roof Overhead

Most spaces on campus today are without any shelter. However, as the student population grows there will be a greater need to build parking decks to meet this increasing capacity.

Safety

Safety is an attribute of the lots contained in the GMU parking system. The safety measure of a space is an approximation of the probability a stakeholder using the lot containing the parking space will be a victim of a crime either to property or person.

Statistics from the number of open spaces in the different lots at peak times (11:30 am – 1:30 pm) of 2001 were used to define the usage in the parking lots during peak hours. The peak usage helped to estimate the probability that a car will enter and use that particular lot during peak hours. The lot usage was then estimated from this probability and the number of decals sold in 2001. The safety probability was obtained from the usage of the lots and the number of crimes in each lot during 2001 obtained from George Mason University Police files.

The crime rate of a lot varied greatly between lots but one factor seemed to play the primary role in these values: how secluded the lot was. Lots M, O, and P had high crime rates as did lot L. Lot B also had a high crime rate. Although it is the busiest lot on campus, this is only between classes. During class time the lot is more or less empty of people and the fact that trees surround it makes hiding one's actions in this lot easy (Jones 2002).

Free Space in Parking Space

Free Space in Parking Space is another attribute of the parking spaces that make up the parking system at George Mason. Free Space within a parking space is a measure of the width of the individual spaces in each of the GMU parking lots.

The measurement of free space is obtained from the width of the space and subtracted from the width of an average sized vehicle, measured in inches. This gives the amount of space within the lines of the parking space allotted after a car is parked.

Parking Space Cost

The cost of the parking space is the expense per hour to park in a particular parking space. This represents all types of parking spaces, which include, metered parking, parking deck spaces, and general parking spaces. The measurement of this metric are recorded in dollars per hour. The parking rates for each type of space are as follows:

$0.25 per 10 minutes	Metered Parking (max 1 hr.)
$1.25 per hour	Parking Deck (max $6.00)
$75.00 per semester	Decal (average full time student attending GMU for a 16 week semester and at 20 hours per week)

Perceived Fairness of Parking System

Perceived Fairness metric is the measure of how equitable the resources of the parking system are distributed among the stakeholders. This function is a combination of all of the attributes, which explains the stakeholders' opinion about the parking system as a whole and how it distributes its resources. This was modeled by taking the difference of the derived utility of the other five performance metrics and comparing this value to the average derived utility from the first five performance metrics.

PARKING SYSTEM MODEL

A model of the George Mason parking system was made for three scenarios. The first scenario simulated the effects on the parking system should nothing be done to change the parking system from its present state. The second scenario simulated the effects on the parking system if the plans being put into effect at this time, as suggested by Sasaki Associates, Inc., were to be followed (Coyne 2002). The final scenario simulated the effect on the parking system should the parking system employ our preferred design.

To model the parking system, a sample set of parking spaces were used to represent the campus parking system and the five performance metrics that are attributes of the parking system's parking spaces were measured for each of these spaces and compiled into an Excel spreadsheet. The weights and utility functions of the stakeholders for all the performance metrics were also put into the Excel spreadsheet. This spreadsheet served as a database of empirical data on both the stakeholders using the parking system and the parking system itself. The spreadsheet also served as the input file to the model.

The model itself was a Visual Basic Monte Carlo Simulation that found a simulated stakeholder's most preferred open and valid parking space slot for the stakeholder, put that stakeholder in that space, and calculated the stakeholder's derived utility. This was done for each stakeholder in a randomly selected sample set of stakeholders. The simulation started with all spaces empty and assumed that once a stakeholder parked in a space he did not leave until after the simulation was over.

SYSTEM DESIGN

Our system contains three components that are policy changes to the existing system. The fact that each of these components are policy changes to the existing system has the advantage of possibly having a significant impact to the effectiveness of the system at a very low price. The system components incorporated in our design are: (1) carpooling incentives, (2) reserved space auctions with differential pricing, and (3) dorm student space restrictions.

Carpooling Incentives

This particular policy change will give any group of stakeholders between two and five people a carpooling decal and a 5% discount per person from the price they would normally pay had they paid for a non-carpooling decal. Those involved in the carpool cannot buy an additional standard decal to make it more difficult for those who default on the carpooling agreement to be able to park. Those who wish to leave the carpooling agreement with their fellow carpoolers can do so and buy a standard decal, but they must pay the full price of the decal plus an additional penalty.

The primary effect of this policy change will be to slightly lower the volume of vehicles entering the campus, and will in turn improve the derived utility of the stakeholders using the system. Although the benefits of providing carpooling incentives will be small, the costs will also be very small. Since it will be difficult for those stakeholders who enter into a carpool to buy a standard decal sticker, most of the enforcement required needed for this policy is already done by standard enforcement of the system and making sure carpoolers do not buy a standard parking decal.

Reserved Space auctions with Differential Pricing

The parking spaces across the George Mason campus vary greatly from one another, and in effect, vary greatly in their value to the stakeholders. Presently, nearly all these parking spaces cost the same price, which leads to a substantial amount of market inefficiency. Stakeholders who would be willing to pay high prices for a guaranteed quality space on campus and stakeholders who are very price sensitive and care little about the distance they have to walk are left unsatisfied with the present parking system's market mechanism. By differentiating the prices of the parking spaces into discrete levels, stakeholders can choose the price level that best suits their needs. This could result in a greater derived utility, although it is more likely that this particular market mechanism would lower the derived utility of the stakeholders slightly but increase the revenue generated by the parking system.

The weakness of a differentiated pricing system is that the stakeholders would become a great deal more price sensitive than with the traditional single price market mechanism. If the prices are set too high for any one level, spaces will be left empty that will tease stakeholders at lower pricing levels, lower the capacity of the parking system, and loose potential revenue. If prices are set too low for any one level then stakeholders who paid for better quality spaces will have to park in lower quality spaces. To ensure that the prices for all spaces are at their equilibrium level, a representative sample set of spaces will be sold by way of an auction that will reveal the true market value of the spaces.

The sample set of spaces to be sold will be reserved spaces sold by way of an auction before the standard decals are sold. Our system design will implement a uniform price sealed bid auction for several sets of parking spaces across the parking system. This way, the optimum price will be found for the reserved space and all spaces should be sold.

Resident Student Space Restrictions

Resident students make up approximately 10% of the campus, and since they are on campus at all hours, have first choice to all parking spaces on campus. Furthermore, the student dorms are located near the center of campus where many of the classrooms are located. The end effect is that resident students park in the best spaces on campus even though they don't have as much use for their vehicles as commuter students and faculty and staff do. Lot B, the most valuable general parking lot on campus, is nearly half full with resident students at all times (SESDP 2001).

This parking system policy will restrict resident students from parking in the most valuable lots on campus, and consequently, improve the derived utility for all the other stakeholder groups at the expense of the resident students. The implementation of this policy is tricky, however, because a policy that puts one group at a disadvantage to all the other stakeholder groups is an inequitable distribution of the parking system's resources. Furthermore, there is no guarantee that the increased utility derived by the other stakeholder groups will be enough to offset the decreased utility of the resident students. As a compromise, our design restricts resident students from purchasing the highest priced decal type in the differentiated pricing market implemented in the parking system at the time, but have spaces designated exclusively to them closest to their dorms.

RESULTS

Our analysis of the results of the model shows that our design consistently had a marginal improvement to the derived utility for the average stakeholder. Figure 5 shows the derived utility of the average stakeholder using the George Mason parking system for each of the three scenarios. The lines representing our policy changes are labeled "Policy Changes x% Carpooling" where x represents the percent reduction in vehicles from carpooling. The effects of carpooling on the volume of vehicles entering the system were measured parametrically.

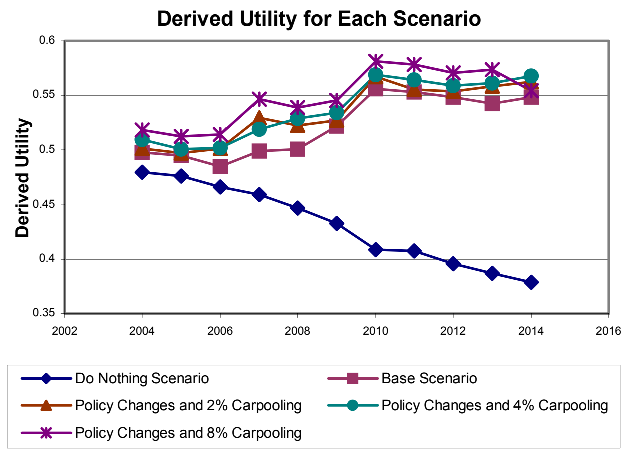

Figure 5. Resulting Derived Utility for each Scenario.

The Do Nothing scenario, where no changes are made from the present system, shows a sharp decrease in the quality of life of the stakeholders. This happens because the parking system capacity does not meet the growing demand placed on it, and hence, up to 10% of the vehicles that enter the parking system simply cannot find parking anywhere on campus.

The Base scenario that creates new parking spaces in pace with demand shows that it is able to improve the stakeholders' quality of life, especially in the later years of our system's life cycle. The plans presently in place will concentrate on building more parking closer to the center of campus, thus raising the value of the average parking space on campus (Coyne 2002).

Our design shows marginal improvement over the Base scenario. However, the difference is only 1 standard deviation, even when it is assumed that the carpool incentives reduce the volume of vehicles by 8%. Therefore, the increase in how effectively the parking system fulfills the needs of its users when implementing our policies will be small, but there will be a definite improvement.

One statistically significant difference between our scenario and the base scenario is the difference in the amount of revenue generated by the parking system. On average, our system generates approximately $1000 more per hour than the base scenario that simply increases the capacity of the parking system. This amounts to nearly $320,000 more revenue per semester and this number grows near the end of our system's life cycle. This increased revenue can help pay for the rapid growth of the parking system that is planned between 2004 and 2020. Furthermore, some of this revenue could be returned to the users of the GMU parking system by way of a discount to the price of the parking stickers, thus increasing the stakeholders' quality of life or helping pay for the increase cost of building high-rise parking garages.

Finally, the cost to implement and maintain our system design is small relative to the revenue it brings in since they are all policy changes that have no material costs. The initial cost of setting up our system is estimated to be approximately $13,000. To maintain our system costs an additional $50,000 annually.

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BIOGRAPHIES

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