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Modeling Parking Demand : A Systems Approach To Parking Policy Analysis On Campus

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MODELING PARKING DEMAND : A SYSTEMS APPROACH TO PARKING POLICY ANALYSIS ON CAMPUS

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ABSTRACT

An economic model of parking behavior (using Vensim PLE software) was designed to consider the relationship between costs and benefits in meeting parking demands of the range of users on an urban university campus. In using Minnesota State University, Mankato campus as the case area, model simulations were run to answer the question of; "how do we price parking permits to minimize parking supply surpluses/shortages on campus and still meet the cost of parking?".

The study results indicated that there is an over-supply of some types of parking spaces and an under-supply of other types when parking demand is determined only by expected permit purchases without considering the peak-use of parking facilities. The over-supply of parking spaces at peak time leads to excess parking costs – in terms of annual operating and maintenance cost – and the under-supply leads to peak time shortages of parking spaces for users. By running these simulations, an "optimum parking price level" – the price that minimizes supply excesses and shortages while ensuring that revenue generated meets at least the annual operating and maintenance costs – was determined for each parking permit category.

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CHAPTER ONE

THE NATURE OF PARKING ON MSU CAMPUS

1.1 Introduction

The increase in the usage of private single occupancy vehicles is significant for planning and design interventions. Planning and design interventions must seek to address infrastructural and sometimes technological demands which are limited in supply. The need for parking space is part of the nexus of demands associated with the upsurge in vehicles plying the roads. Shen (1997) argues that population growth and increasing standards of living are to blame for the rise in the number of cars in cities. It is estimated by Shoup (2005) that the average car is parked 95 per cent of the time. Litman (2012b, p. 2) also avers that "a typical automobile is parked 23 hours each day, and uses several parking spaces each week". Hence, the need for parking space and its related analysis cannot be over emphasized.

From the foregoing discussion, the supply of parking spaces requires the provision of parking infrastructure. Parking spaces are a critical element in transport and other infrastructure design, and limited funds have been a factor in the inability to provide these parking facilities. Frequently, the supply of these parking facilities has not yielded commensurate financial returns to the providers of these parking facilities. Consequently, the need to supply the increasing demand for parking spaces in light of the limited financial resources at disposal has recently given rise to parking pricing measures. These measures demand that parking users pay for the use of parking spaces either by the hour, day, month or year of usage. Studies have demonstrated that charging can reduce car use, and hence relieve congestion and the environment; it also provides a source of net revenue (Feeney, 1989; Shoup, 2005). Charging for parking cars according to May (2004) is an effective parking control tool to reduce demand for car use as practiced in Singapore. However, this study considers the pay as you park service as a revenue generation means but not as a prohibitive mechanism against car use.

1.2 Parking and Universities

In many cities, universities with their staff and their student populations account for a significant proportion of the urban population. The provision of transport infrastructure, of which parking facilities form an important component, has been a major responsibility for the university authorities. University campuses present a particular problem since they combine pedestrian and vehicular travel modes, and conflicts are frequent, yet the standard texts on campus planning (see Dober, 1996) are silent on the topic. Hence, the need for empirical analysis of parking space and related transportation issues on campuses cannot be over emphasized. The significant interest here is to understand the relationships (in economic and environmental terms) between the cost of meeting the increasing parking demand and the formal benefits derived from that provision.

As important as parking is in transportation and other infrastructure designs, limited resources (of money and of space) have restricted the ability of campuses to provide these parking facilities, hence the introduction of parking pricing measures. Such measures however require the determination of; the price level (Shoup 2008 and Litman 2011) to balance demand and supply, the associated costs and benefits to the campus, and how this will affect transit on campuses.

Existing vehicle parking literature deals not only with charging for the use of these parking spaces to generate enough funds, but also, the "how" involved in determining the "right" amount. In his article on "The Politics and Economics of Parking on Campus", Shoup makes the case that "faulty pricing" has become the problem with the parking pricing systems implemented by University authorities.

The challenges of parking are exacerbated as campuses and cities in general determine parking supply by using parking requirements (Tumlin, 2012; Shoup, 1999, 2005, 2011; and Shoup and Pickrell, 1978) without paying much attention on how much it will cost (direct and indirect) now and in the future as we build and convert available lands to meet these parking requirements.

Since we cannot continue to convert all our available lands to meet the seemingly insatiable parking needs of a population dependent on private vehicles, there needs to be a way out. This is especially important as parking budgets on campuses often are colossal sums of money. To do this an economic model that balances demand and supply without distorting the balance between cost and benefits will be developed in this study, using Minnesota State University, Mankato campus as a case study.

1.3 Research Statement, Goal and Questions

University campuses are supplying increasing parking needs with their limited funds by using several permit schemes to raise revenue in off-setting the cost of providing and maintaining these parking facilities. The area of inquiry here is the extent to which such permit schemes off-set the cost of meeting such parking demands.

1.3.1 Research Hypothesis

Null Hypothesis (H_0): Cost may exceed benefits to meet parking demand.

Alternative Hypothesis (H_1): Cost may not exceed benefits to meet parking demand.

1.3.2 Research Goal

The goal of this research is to develop a parking model which considers the relationship between costs and benefits in meeting parking demand to answer the question, How much should a campus charge for parking spaces to ensure an optimal balance between parking demand and supply?

1.3.3 Research Questions

To achieve this research goal and answer the main question stated above, these auxiliary questions provide the basis and framework which put the study in context:

- What is the relationship between parking demand, supply and transit on campus?
- If parking demand is met:

  a. Apart from the economic cost, what other costs will be incurred?

  b. What will be its impacts on transit to the campus?

- What level of demand and supply will achieve an optimal parking balance on campus?

  a. What should be the price (optimum parking price) paid by parking users at this level?

- How does transit provision help in reducing parking demand and vice versa?

1.4 Organization of Study

The study is organized into seven chapters with each chapter serving as inputs for other chapters. The first chapter discusses the nature of parking on campuses, using Minnesota State University (MSU) as the study area. The second contextualizes the study by narrowing down to specific theoretic and conceptual discussions of existing literatures on parking demand, supply, cost and supply relationships. Throughout the chapter, reference is made to the implication of the concepts on the study's focus, so as to dissect each concept to know which aspects of the concept can be adopted and made relevant to this study.

The third chapter looks into the methods applied in conducting the study. It elucidates the details of the way each method helped achieve the objectives of the study. The fourth chapter then starts the discussion of the existing parking situation on campus. This is done by presenting descriptive statistics from a parking occupancy survey, parking pricing regimes, and their implications on the current parking situation. Based on these conditions, the fifth chapter analyzes the relationships existing between parking demand, supply, cost and benefits on campus.

The sixth chapter develops the parking policy analysis side of the study. It discusses the parking economic model, the simulations conducted, and the implications of the simulations on the hypothesis, and the how that could inform future parking policy on campus. The study is concluded in the seventh chapter, which summarizes the major findings and then offers both short-term and long-term recommendations for parking policy actions based on the major findings.

1.5 Operational Definitions

Transportation Demand Management (TDM): This is seen more as a general term used to describe strategies aimed at a more efficient use of transportation resources (Victoria Transport Policy Institute, 2011). It can also be used as Travel Demand Management, which is defined by the Federal Highway Administration (FHWA, 2004) as "optimizing transportation system performance for commute and non-commute trips and for recurring as well as non-recurring events".

Induced Demand/travel: Increased/realized total vehicle miles travel (VMT) compared with what would otherwise occur due to improved transportation system -any improvement that decreases travel time and cost- (Hills 1996; Cervero, 2001; Rodier, 2004; Mokhtarian, 2004; and Litman, 2012c).

Campus Parking Users/User Groups: These are the people who use the parking facilities on campus. These include on-campus students (resident and non-resident/commuter students), faculty, staff and visitors. In this study the two main groups considered are students, and the faculty and staff. Also, the faculty and staff categories were grouped into one main category often referred to in the study as faculty/staff. For consistency, the total number for each of these user groups has been determined using the fall semester record of the academic years considered for the study (2002/2003 to 2010/2011). The visitor category will be referred to from time to time, but is not used in the mathematical model.

- *On-campus students:* This is the headcount of all students enrolled in one or more courses which will require them to come to the MSU, Mankato campus for at least once a week in a semester.
- *Resident Students:* The total headcount of all students (mostly First-Year students) who are housed in MSU's residence halls for at least a semester.
- *Non-resident/Commuter Students:* Headcount total of all on-campus students who are non-resident students. These are also referred to as commuter students in the study..
- *Faculty/Staff:* The total number of Full Time Equivalent and Part-time faculty and administrative staff of MSU. This is basically the total employees of MSU with the exception of student employees (undergraduate and graduate teaching, research and administrative assistants).
- *Visitors:* These are the total number of people who occasionally visit campus.

Optimal Parking Demand and Supply Balance/Optimal Parking Balance: This is that level of parking demand and supply where surplus supply is minimized and the cost incurred in parking does not exceed the benefits provided.

Optimum Parking Price: This is the price paid by parking users to achieve optimal parking balance.

Parking Permit Categories: These are the various color and use designations assigned to parking facilities on campus. For this study, the gold, orange, purple, light and dark green categories will be considered. The gold, orange and purple permits can be purchased by non-resident students and faculty/staff. The light and dark green permits can only be purchased by the residence hall students.

Off-street Parking: MSU parking facilities on its own land, not on public rights-of-way.

On-street Parking: Parking lanes provided along the right-of-way of roads on campus.

Parking Lot: The covered surface land area that have been divided into parking spaces/stalls. In MSU, these are primarily off-street parking lots and the study considers 19 out of the 34 off-street parking facilities (the remaining lots are for administrative use, not available for student/.faculty parking). The spaces/stalls in the 19 lots studied make up 77% of the total parking spaces and 85% of the total off-street spaces in MSU.

Parking Space/Stall: A square unit of an area where a vehicle can park without being restricted by another vehicle. A total of 3,824 off-street spaces were studied.

Parking Occupancy Level/Rate: This is the total number of occupied parking spaces/stalls at a given time period. It is normally expressed as a percentage. For instance, a total of 8 out of 10 spaces occupied at the 10-11am hour will return an occupancy level/rate of 80%.

Vacancy Level/Rate: This is the total number of unoccupied parking spaces at a time period. Thus, an occupancy level/rate of 80% means a vacancy rate of 20%.

Peak Time/Hour/Period: This is the time period within which the highest occupancy level/rate occurs.

Parking Demand/Target Demand: This is the total number of spaces that are needed by the parking users on campus at the peak period. This is determined by calculating the demand ratio for each group of parking users on campus. It is also known as "Peak Permit Use/Demand."

Demand Ratio: The demand ratio as defined by Walker Parking Consult (2005) is the number of vehicles observed to occupy parking spaces compared to a reference statistic. For instance, with a total of 2000 faculty/staff members, if the observed number of vehicles parked by faculty/staff members at the peak hour is 1000, then the demand ratio is 0.5 (1000/2000) spaces per faculty/staff member. As simple as it may look like, the computations might be complex since it is difficult to know which vehicle belongs to which user at that time period. Alternatively, the demand ratio is also expressed as the presence ratio/factor multiplied by the driving ratio/factor.

The Presence Ratio/Factor: This is the portion of a parking user group present during the peak time.

The Driving Ratio/Factor: Although expressed by Walker Parking Consult (2005) as the percentage of a user group that drives a vehicle to campus or has a vehicle on campus;

however, not all those who drive to campus will park on campus, since some may be dropped off and picked up later. Further, it might take a carefully constructed sample survey to determine this. Since more specific data exist on this issue, the driving ratio as used in this study will be expressed as the percentage of a user group that purchase parking permits on campus. By this we know that people who purchase a permit will definitely park on campus. It also means that those people drive or are driven to campus. And our only interest here is to find the number who park on campus not necessarily those who drive.

Parking Supply: This is the total number of parking spaces provided at a point in time in meeting the parking demand on campus. Parking supply is expressed in terms of its effective supply and not the total supply.

Effective Supply/85% Occupancy/Target Supply: The principle of effective parking supply implies the maximum number of on-street and off-street parking spaces available for supply. It is a generally accepted principle that parking achieves optimum efficiency at 85% to 95% occupancy (this study mainly uses the 85% level when discussing the current parking situation, and uses the 95% for the model predictions, in which case it is referred to as the "Target Supply"). Effective parking supply explains that 100% of the total parking supply or capacity is not always usable since a small reserve is needed to allow for the dynamics of vehicles moving in and out, daily, weekly and seasonal variations, vacancies created by restricting facilities to certain user groups, improperly parked vehicles, and minor maintenance or construction.

Parking Supply Excess: This is the number of parking spaces left at a given surplus level. A negative, positive or zero excess means there is either a shortage, surplus or balanced number of parking spaces. It is normally determined at two different levels:

- *Overall parking excess:* This is the total number of spaces left when a number of parking spaces are occupied. For instance, when the total parking spaces in 100 and if 80 are occupied, then the overall parking excess is 20.
- *Parking Excess at the Effective Supply/85% Occupancy:* This is the total spaces left when the total spaces are set at the effective supply level and not the overall total spaces. For instance, with a total of 100 spaces, if an effectively supply of 85% is set, the total spaces will be 85 spaces instead of 100. Therefore when 80 spaces are occupied, then the parking excess at the effective supply/85% occupancy is 5 spaces and not 20 spaces as measured by the overall parking excess.

Parking Permit Price/Fees: This is the amount charged per parking space occupied. In MSU, except for the visitors lot, the permit-based spaces are priced per semester or year.

Parking Cost/Total Cost: This is the cost involved in constructing a unit of parking space. It encapsulate costs like the economic cost/price (cost with or without profit margin), and the market cost (the economic and societal cost). The total cost therefore comprises of the annual operating and maintenance (OM) cost and the construction/capital cost for each unit of parking space/stall.

Parking Benefit/Revenue: This is the estimated revenue generated by each parking space/stall.

Transit: This refers to the mass movement of people or goods within the campus area either through the Mankato Mass Transit or the MSU's shuttle services.

Alternative Parking Users/Parking Substitutes/Non-Parking Users: Parking substitutes or alternatives parking users here refers to the other factors/variables that can affect parking demand on campus. Normally, these factors refer to the other means by which people can move to campus without driving to campus alone in their private vehicles. In the model, an increase or decrease of these people is mainly determined by an increase in parking permit prices.

CHAPTER TWO

PARKING DEMAND AND SUPPLY RELATIONSHIP TO COSTS AND BENEFITS: THEORETIC AND CONCEPTUAL DISCUSSIONS

2.1 Introduction

Parking as a derivative of trip generation (Regidor, 2006) in transportation planning refers to either off-street (surface or structured) or on-street parking or even both. To comfortably situate this Chapter within the context of the prevailing theoretic discussions, parking, as used here will refer to off-street parking facilities. Parking demand and supply has widely been determined through the use of requirements stated in zoning codes (Tumlin, 2012; Shoup, 1999, 2005, 2011; and Shoup and Pickrell, 1978) but that scarcely gives consideration to how much it will cost (direct and indirect) now and in the future as we build and convert available lands to meet parking requirements.

As Litman (2012b) and Shoup (2008) argue that even such parking requirements have inherent errors which makes them questionable, they propose alternatives such as the Efficiency-based and the Goldilocks principle [1] of parking prices of demand and supply. These alternatives implicit in them takes care of the direct and indirect cost elements in ensuring that the number of parking spaces demanded and supplied are balanced at what is known as the performance-based price. The process in reaching this performance-based price is therefore conceptually presented by Martens and van Luipen (2009) in what they refer to as the "Integral" approach in determining the "right price" of parking.

[1] The Efficiency-based and the Goldilocks principle are explained subsequently in this Chapter

In a chronological and methodological manner (Craswell, 2005), the idea presented in this discussion is a synoptic and succinct literature perspectives related to parking demand and supply as well as costs and benefits. Throughout the discussions, deliberate efforts are made in shaping such perspectives to suit the case of parking on campus.

2.2 Parking Demand and Supply

The determination of the demand and supply levels, although a market system approach[2], is seen by others to offers the foundation for an efficient and equitable decision-making [3] from both the production and consumption viewpoints. Price determination from the classical economic view point is therefore seen to be equitable when demand and supply intersects, also known as the equilibrium point (Stigler, 1941; and Chapra, 1991).

In campus parking ironically, this basic economic proposition has limited role in determining the levels of demand, supply and pricing for campus parking facilities. The irony here is well alluded to by Shoup(2008) in his paper on "the politics and economics of parking on campus", when he describes campus parking decision-making making process and it resultant policies as that which makes little or not room for an emotion and

2 Market system is defined by Chapra (1991) as the reformed capitalism, which combines the principles embodied in *laissez-faire* capitalism and the welfare state

3 Equity and Efficiency associated with the market system or socialism has extensively been debated (See "The Need for a New Economic System" by Chapra, 1991). Even though Chapra states that the market system is a logical outcome of the assumed symmetry between public and private interests, he further argues the flaws in the system and supports his claims with the assertion that few economists will be willing to support the idea of equity. But his arguments does not preclude the possibility of achieving both efficiency and equity in the market systems since implicit in his proposition is the idea of a new economic system that corrects the flaws that the old ones already have in terms of achieving equity and efficiency.

politics free discussions, which campuses were expected to hold as the custodians of intellectual and transparent decision-making arm of society.

The demand and supply for parking of an area are informed by the vehicle ownership, trip rates, mode split, duration (how long motorists park), geographic location, the quality of travel alternatives, type of trip, and factors such as fuel and road pricing (MRSC, 2012 and Litman, 2012c). As to whether demand influences supply or vice versa in parking planning, are issues of conceptual debates closely related to "demand-induced-supply" versus "supply-induced-demand"[4] in parking planning. In the midst of these debates, which forms the basis for campus and other city parking policies is the one fact that, issues of demand and supply are closely tied to cost and benefits.

Let's consider it this way, should you decide to supply parking spaces in anticipation of future demand, those who could have thought of transit and among other economically and environmentally efficient alternative means of transport to their destinations will now have the incentive to drive their own vehicles since there are parking spaces available. Similarly, when the approach is such that, parking spaces are supplied as and when there is a demand (mostly determined through spill-over parking or long search duration for parking spaces by users), the same scenario as in the case of the former will emerge. Therefore, irrespective of the approach adopted, the determination here should be on the costs and benefits that should be anticipated in supplying the parking spaces demanded.

[4] Shoup (2008) alludes to an argument similar to this by stating that, "The phenomenon of vehicle travel induced by new parking spaces (added vehicle-storing) is similar to vehicle travel induced by new roads (added vehicle-carrying) capacity" (p. 134)

In his discussion of the "paradigm shift" in parking planning (as summarized in Table 2.1), Litman (2012b) brings to the fore that the new order of things relates to the how problems are perceived and solutions evaluated. Thus, while the old paradigm focuses on maximizing supply and minimizing price, the new paradigm considers too much supply as harmful as too little, and prices that too low as harmful as those that are too high (ibid). This way, the new paradigm in parking planning, tries to maintain the balance between demand and supply as well as cost and benefits, to both users and suppliers.

Table 2.1: Old and New Parking Paradigms Compared

Old Parking Paradigm	**New Parking Paradigm**
"Parking problem" means inadequate parking supply.	There can be many types of parking problems, including inadequate or excessive supply, too low or high prices, inadequate user information, and inefficient management.
Abundant parking supply is always desirable.	Too much supply is as harmful as too little.
Parking should generally be provided free, funded indirectly, through rents and taxes.	As much as possible, users should pay directly for parking facilities.
Parking should be available on a first-come basis.	Parking should be regulated to favor higher priority uses and encourage efficiency.
Parking requirements should be applied rigidly, without exception or variation.	Parking requirements should reflect each particular situation, and should be applied flexibly.
Innovation faces a high burden of proof and should only be applied if proven and widely accepted.	Innovations should be encouraged, since even unsuccessful experiments often provide useful information.
Parking management is a last resort, to be applied only if increasing supply is infeasible.	Parking management programs should be widely applied to prevent parking problems.
"Transportation" means driving. Land use dispersion (sprawl) is acceptable or even desirable.	Driving is just one type of transport. Dispersed, automobile dependent land use patterns can be undesirable.

Source: Litman, 2012b

2.2.1 Parking Demand and Supply Determination

The number of parking spaces demanded is mostly defined by the parking requirements stipulated in the zoning code. It is therefore expressed as a unit space per square unit of an area. Litman (2012b) suggests this method of providing indexes or ratios for parking gives unconstrained and unadjusted values. Hence, such indexes or ratios only reflect the maximum supply that could be needed (ibid) and often adjusted significantly downward (Topp, 2009).

Consequently, parking demand according to Litman (2012b) has therefore been determined through parking surveys at 85th percentile demand curves (implying that facility is full if 85% of spaces are occupied at the peak period), and at 10th design hour (implying parking hours are full only 10 hours per day).

The 85th percentile as an industry standard in itself may vary based on the land location and its uses, parking pricing options, and the alternative transportation options available to the people. Again, what is the parking situation like, beyond the 10 hours or any stipulated hours in which parking occupancy is determined. The errors inherent in such standards therefore are seen by Litman (2012b) to point towards the oversupply of parking spaces in many ways. As already posited, the issue then becomes the costs and benefits associated with such oversupply oriented policies.

On campuses and even in cities, the phenomenon of such oversupply oriented policies will only be manifested when there are several vacant spaces scattered all over the parking facilities, even at peak periods. The argument here is not to put forward the idea that there is a perfect system of determining parking demand and supply. Instead, it only seeks to clarify the position that, existing parking models mostly lean towards an over estimation of what needs to supplied. Without considering the location, land uses, alternative transportation options, and most importantly the parking prices, parking policies might overestimate the demand and hence the supply. And when this occurs the costs and benefits results is quite obvious, especially when indirect costs like storm water management and other environmental consequences are factored into the equation.

2.2.2 Efficiency-Based Standards and the Goldilocks Principle of Determining Parking Demand and Supply

In using efficiency-based standards to determine parking demand and supply, Litman (2012b) observes that such standards take into account the location, demographic and economic factors affecting parking demand. With this," less parking is supplied where parking supply is relatively costly to provide or where management programs (are) easy to implement" (ibid, p. 10). He moves further to support this point by bringing in ***contingency-based planning***, which is what the efficiency-based planning relies on. With the contingency-based planning, lower parking standards are set, monitored and revised. Here, there is the confidence that any problem that may arise can be dealt with through monitoring and revision programs.

Shoup (2008) however takes the discussion further in a much specific and simplistic manner in theorizing parking demand and supply determination through the lens of the Goldilocks principle of parking demand and supply. He refers to this principle also as the ***performance-based approach*** in parking demand and supply analysis. The exegesis of this principle is rooted in the proposition that the demand and supply of parking is best determined when ***"price"*** [5] is considered. Price takes care of the direct and sometimes indirect costs supplying parking facilities, which also aids determine the benefits (revenue) accrue from parking. Similarly, the price, which when determined based on the identified factors like location, other land uses and alternative transportation to users, will determine **how many** parking spaces will be demanded, ***when*** (period of the day and weekdays, and ***when*** they will be demanded.

2.2.3 The Balance between Demand and Supply

With the introduction of pricing in the determination of the demand and supply levels, the Goldilocks principle of parking indicates the level at which demand balances/equals supply (performance-based price or equilibrium point) using pricing levels. Shoup (2008, p. 136), therefore states that, "the Goldilocks principle of parking prices to balance supply and demand: the price at any location is too high if many spaces are vacant, and too low if no spaces are vacant". In this respect, the performance-based price where parking demand meets supply can be inferred as that price level, few vacant spaces, at an acceptable occupancy rate (between 84 to 96 percent), are available everywhere. At this price level, Shoup (2008) opines that not only will parking be just right, drivers can also find a place to park.

In his illustration of how demand balances supply at the performance-based price or equilibrium, Shoup uses the diagram presentation as Figure 2.1. With supply fixed at an

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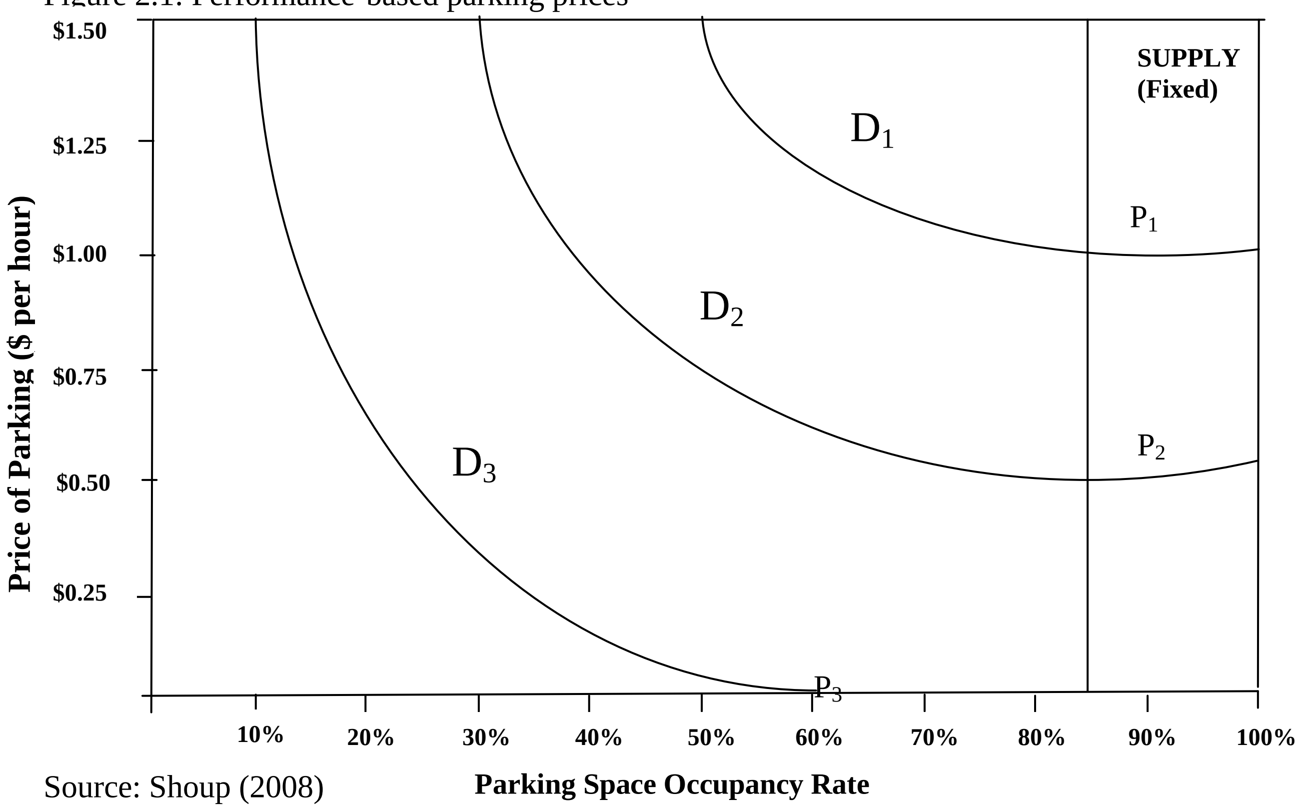
[5] Tumlin (2012) adds "time limits" and "payment mechanisms". He argues that "pricing" should be based on "time-of-day parking rates" and not "progressive parking rates".

85% occupancy rate, represented by the vertical line, the downward sloping demand curves (D1, D2 and D3) will intersect the supply curve at points P1, P2 and P3, which are the performance-based prices. At Point P1, the demand is high, which means that to ensure that the parking spaces supplied meets the demand to create a vacancy rate of 15percent, then the right price should be $1 an hour. At a moderate demand level of D2 and a low demand level of D3, a price of $0.50 and $0 an hour respectively will make the demand balance supply.

Figure 2.1: Performance-based parking prices



Source: Shoup (2008)

The responsiveness of this performance-based pricing in adjusting demand and supply to ensure a balance rests in the argument put forward by Shoup (2008) and Tumlin (2012) that, since parking supply is fixed as demand fluctuates within the day, the demand-responsive pricing will rise and fall to maintain the desired vacancy rate. He therefore suggest the use of electronic parking meters to charge variable prices in-between parking hours, based on monitored occupancy rates.

2.2.4 Determining the Optimal Parking Balance in MSU: A Blend of the Contingency-based Planning and the Performance-based Pricing Concepts

Parking pricing in MSU is done on semester and year basis. Performance-based pricing operates on having a daily means of parking pricing. Shoup therefore suggests the use of electronic parking meters which changes parking prices by the hour based on demand. The focus of this study only seeks to adopt the idea behind parking pricing as introduced in the performance-based pricing concept i.e. the idea that demand and supply should be regulated by price. Hence, the study seeks to apply this idea by finding out, how much MSU should charge for its parking year/semester permits based on certain demand and supply levels.

Contingency-based planning also focuses on being mindful of parking supply cost hence, supplying the minimum supply to ensure the minimum parking cost. This aspect of the concept is also adopted in this study to examine the cost associated with every level of supply that the University wishes to provide. There is therefore a synthesis of ideas from both concepts which has to deal with supply, demand, price and cost.

The contingency-based planning requires that parking be supplied at that minimum cost while the performance-based pricing makes the case that supply should meet demand at the possible minimum cost to both the user and the supplier. At the core of both concepts lies the fundamental issue of cost and supply relationship, which does inform parking prices. Reducing price should mean reducing cost of supply. If supply is in excess of what is demanded, then cost will also be in excess, which makes users pay more than they have to. On campuses where parking prices are mostly subsidized by the University, the excess cost often becomes the responsibility of the University in the form of annual parking budget deficits.

A synthesis of the concepts and the ideas adopted for the study presents the following considerations that:

- Parking supply must try to meet demand to avoid supply excesses and cost (contingency-based planning); and
- Parking supply be at that price level which offers the minimum cost to suppliers and the least total social value of time spent walking between parking spaces and destinations to users (performance-based pricing).

In the determination of "how much to charge for campus parking" there needs to be a price level (an optimum parking price), which does not only minimize supply excesses, but it should also ensure that at least, the annual OM cost thereof does not exceed the benefits/revenue. This is what this study refers to as the "Optimal Parking Demand and Supply Balance" Or just the "Optimal Parking Balance"

2.3 The Cost and Benefits of Parking

Parking Costs

In relating cost to parking, the discussion mostly narrows down to the direct cost of providing parking facilities. Growing environmental concerns in all spheres of development discussions have brought in the element of indirect cost of providing parking facilities (Litman, 2012b; Shoup, 2011 and VTPI, 2012). Litman (2012b) and the VTPI (2012) therefore define parking costs to include the direct and indirect costs. While the former deals with the cost of land, construction, operation and maintenance costs, the latter brings in the environmental cost element. Such environmental costs include "green space loss (reduced landscaping, farmland, wildlife habitat, etc), increased impervious surfaces, and related storm water management costs" (Litman, 2002; p. 5.4-4).

The issue of land having the potential of being put to other uses, aside parking provision, gears the debate towards the opportunity cost incurred (Manville and Shoup, 2005; and VTPI, 2012), as land is being used for parking. Campus lands, which bears resemblance to lands in the urban areas by virtue of them having competing uses and hence high values, can be put to uses such as conversion to parks or even sold (VTPI, 2012). These become the opportunity cost of land for parking and thus, the costs of parking cannot be treated as a onetime payment of construction cost and some recurring operational and maintenance expenses. Besides, the direct cost of parking on campuses is estimated by Litman (2011) to represent 5-15% of typical campus or building cost.

Litman (2012b) in his literature brings out the following findings:

- "Shoup (1999) estimates that providing minimum parking requirements costs an average of $31 or more per square foot of developed building floor area in typical U.S. cities, 4.4 times more than all other impact fees combined...parking costs average $12,000 per vehicle (about twice the value of a vehicle), and external parking costs total $127-374 billion in the U.S., more than the value of the total roadway system, averaging more than 22¢ per vehicle mile." (Litman, 2012b; p. 5.4-18).
- "Willson (1997) estimates the monthly cost that developers would need to charge for “free” suburban surface and structure parking to be approximately $50 and $100 per space, but because generous parking requirements lead to tremendous oversupply, the “utilization-adjusted break-even fee” would be about twice these amounts, $92 per for surface parking and $161 per for structure parking." (Litman, 2012b; p. 5.4-18)
- A study of land values for transport facilities by Woudsma, Litman, and Weisbrod (2006) indicates that "...urban land values typically range from $100 to $200 per square meter." (Litman, 2012b; p. 5.4-18)

Parking Benefit

Parking benefit on the other hand has always been expressed in terms of revenues accrued.[6] Litman (2011) suggests the use of marginal rather than average benefit analysis in quantifying the benefits of parking. The starting point of his arguments is based on the

[6] Litman (2011) notes an important consideration for parking as a significant revenue generation tool for campuses and municipalities based on how it is administered. He opines that:

"Where parking is managed to maximize motorist convenience, with revenues used to finance additional parking supply, net revenues are generally small, generating less than 1% of total municipal or campus revenues. However, where parking is managed to maximize revenues, parking can generate 5-10% of total municipal or campus revenues" (p. 11) thought that not all parking spaces will generate revenue during the day. Some parking spaces are only occupied at peak periods since they may not offer the most convenient (mostly in terms of proximity assessment) to parking users. This way, determining the benefit as a result of a unit of parking space occupied within the day or the incremental benefits, gives a more accurate description of parking benefits.

In further justifying his view on the benefit of parking in terms of revenue generation, Litman (2011b, p. 11) suggest the following as among the ancillary benefits that could be realized by using the net parking revenue. In the case of campuses, such ancillary benefits can readily be appreciated if it helps to off-set the cost of transit as a means of reducing auto dependency, and also providing convenient and cheaper transportation alternatives.

- Recover parking pricing costs (equipment, enforcement, user information, etc.);
- Recover parking facility construction and operating expenses;
- Recover the equivalent of rent and taxes on parking facilities;
- Parking and transportation management program expenses, including commute trip reduction programs and improvements to alternative modes that reduce parking and traffic problems;
- Municipal transportation expenses (street and sidewalk capital and operating expenses); and
- Special district and neighborhood improvements, such as streetscaping, improved street and sidewalk cleaning and security, and commercial district marketing.

2.4 Parking Demand and Supply vs. Cost and Benefits: The Integral Approach

The common thread in discussing parking demand and supply on one side and cost and benefits on the other is "Pricing". As discussed earlier, when parking demand and supply are regulated based on "price", then the decision as to what will be the cost and benefits can be made using the price levels. As Shoup (2008) and Litman (2012b) assert, this price should vary within the parking hours, since that is the only way that the existing supply can be managed to meet demand.

Not only that, Shoup (2008) argues that this will also help determine the parking overflows or excesses at specific points and at specific hours which can be used to determine how many parking spaces to supply or eliminate, as well as the location and timing. The wrong parking pricing which mostly falls beyond the marginal cost according to Shoup (2008) creates a seemingly insatiable demand for parking spaces on campus, while the opposite holds true for parking above the marginal cost. He further argues that, "inept distribution of underpriced permits leads to a bloated and highly subsidized parking supply" (ibid, 133)

In reference to "Pricing" as the common thread in ensuring the balance, the question then asked is, what should be the "right price" in maintaining this balance. The "right-price" as discussed by Shoup (2008) is not to maximize profits but to help minimize or prevent parking shortages. The integral approach put forward by Martens and van Luipen (2009) and shown in Figure 2.2, offers a conceptual model in making decisions regarding the "right price" for parking, balances demand and supply with due consideration for costs and benefits. At such a right-price, Litman (2011b, p. 28) suggests the following as the benefits that can be realized:

- ❖ Insures that a parking space is virtually always available, increasing user convenience and reducing cruising for parking;
- ❖ Makes the most convenient spaces available for higher value trips and encourages longer term parkers to use less convenient spaces;
- ❖ Tends to be more flexible to users, and more cost effective to enforce than regulations;
- ❖ Reduces total vehicle travel and therefore traffic congestion, roadway costs, accidents, energy;
- ❖ consumption and pollution emissions;
- ❖ Generates revenues, so motorists help pay for the local parking and roadway facilities used;. and
- ❖ Insures that motorists, including non-residents, help finance local road and parking facilities.

As to the appropriateness of pricing in parking decisions on campuses and or in cities, Litman (2011) also brings to bear some decision-making points as to when to consider the right parking pricing policies that takes care of not only the pricing, but also the timing and payment mechanisms (as suggested by Tumlin, 2012). Such points, when reframed in the context of campus parking policies can therefore be seen as follows:

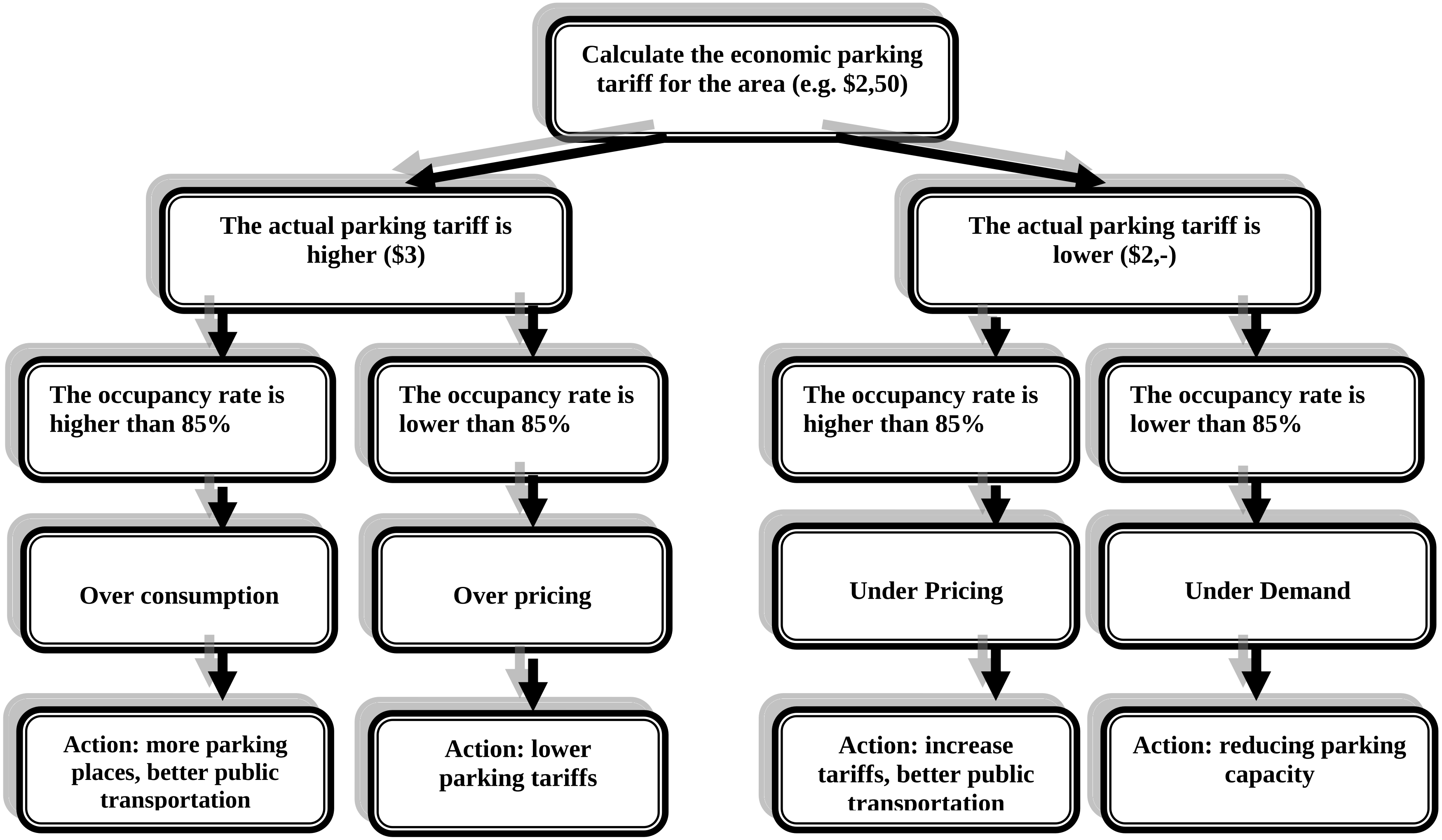
• Where parking facilities are costly / where land is valuable;

• Where there is the need to encourage use of alternative modes to reduce traffic congestion, energy consumption or pollution emissions (Sustainable Campuses);

• Where environmental protection or community livability justify efforts to reduce impervious surface area (the amount of paved land) and total vehicle travel (Greener Campuses); and

• Where there is the need to generate additional revenues to off-set the cost of transit on campuses.

Figure 2.2: The Integral Conceptual Model in Determining the "Right Price" for parking



Source: Adapted from Martens and van Luipen (2009).

2.5 Parking and Transit: "Birds of Similar Feathers"

The idea of planning for parking without considering transit exposes transportation planning deficiencies too early in the process. If our cities don't have any space to park our vehicles, what choice do we have than to consider other alternatives means of reaching our destinations? But these alternatives also need to exist before they can be considered. Meaning, the absence of alternative transport means may also influence the demand for parking spaces.

Advancing this argument further was a survey conducted by the Federal Transit Administration (FTA) in 2002 stated that more than half (56%) of transit passengers report that if transit service were unavailable they would have travelled by automobile, either as a driver or passenger. Also a study by Kuzmyak, Weinberger and Levinson (2003) showed that transit ridership reduced by 0.77% as downtown parking supply increased by 1%. This suggest a fairly strong correlation between transit and parking supply, which affirms to an extent, the assertion made of a symbiotic relationship between parking supply and transit. Notice is also taken in this case, as Litman (2011) rightly points out that factors like walkability and transit service quality may have contributed to the findings in either studies.

Notwithstanding the fact that the demographic, economic, geographic conditions prevailing as well as the nature and purpose of travel play a crucial role in the choice of travel modes and the resultant shifts, Pratt (1999) concludes that, ridership tends to be one-third to two-thirds as responsive to a fare change as it is to an equivalent percentage change in service, and most responsive to combinations of service improvements and fare reductions. Also, when automobile travel decline as a result of road, parking or fuel price increases, a portion of travel shifts to alternative modes, whereas transit service improvements tend to attract more riders, a portion of which substitutes for driving (Litman,2011b).

2.5.1 Using Transit to Manage Parking Demand and Supply

In capitalizing on the mutual relationship between transit and parking in managing parking demand and supply, what needs to be considered is the transit elasticity. [7] The elasticity of transit ridership with respect to fares is believed (Litman, 2011) to be about –0.3 to –0.5 in the short run (first year) and increases to about –0.6 to –0.9 over the long run (five to ten years). Evans (2004) suggests that the elasticity of transit use to service expansion (e.g. routes into new parts of a community) is typically in the range of 0.6 to 1.0, although much lower and higher response rates are also found (from less than 0.3 to more than 1.0). The elasticity of transit use with respect to transit service frequency (called headway elasticity) averages 0.5. In University towns and suburbs with rail stations to feed, he suggests that higher service elasticities often occur with new express transit service.

Interesting in this discussion are findings from studies which suggest that parking prices (and probably road tolls) tend to have a greater impact on transit ridership than other

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[7] This according to Litman (2011) varies depending on factors such as the demographic factors (i.e., the portion of the population that is transit dependent or lower-income), geographic factors (i.e., population density, employment density and pedestrian accessibility), service quality (i.e., speed, comfort and schedule information) and fare price. Also, transit dependent people are generally less price sensitive and discretionary riders more price sensitive. As per capita wealth, drivers, vehicles and transport options increase, transit elasticities are likely to increase (ibid).

vehicle costs, such as fuel, typically by a factor of 1.5 to 2.0, because they are paid directly on a per-trip basis (Litman, 2011). This off-course is applicable if parking prices are considered on a marginal cost basis (hourly or daily cost) than on an average basis (monthly, semester or yearly costs). In addition he summarizes the following as key issues in using transit to manage parking demand and supply. These include the view that:

- ❖ Transit price elasticities are lower for existing (transit dependent) riders than for new (discretionary) riders, and lower in urban areas than for suburban commuters;
- ❖ Elasticities are about twice as high for off-peak and leisure travel as for peak-period and commute travel;
- ❖ Transit price elasticities are relatively high for efforts to shift automobile travel to transit as a demand management strategy (i.e., a relatively large fare reduction is needed to attract motorists), although improved transit services or increased automobile operating costs through road or parking pricing are likely to increase the impacts of fare reductions;
- ❖ Discretionary ridership is often more responsive to service quality (speed, frequency and comfort) than fares;
- ❖ Packages of incentives that include fare reduction or discounted passes, increased service and improved marketing can be particularly effective at increasing ridership;
- ❖ Cross-elasticities between transit and automobile travel are relatively low in the short run (0.05), but increase over the long run (probably to 0.3 and perhaps as high as 0.4); and

- Due to variability and uncertainty it is preferable to use a range rather than single point
- Values for elasticity analysis as much as possible.

In translating these ideas as to how transit can be used to manage parking demand and supply on campuses, Tumlin (2012) and Shoup (2008, 2011) offer suggestions as to the use of the parking revenue generated, to help increase the transit elasticity on campuses. The feasibility of this idea rests with the initiation and expansion of programs aimed at providing:

- Universal Free Public Transit Passes on Campuses;
- Expansion and Improvement of Transit Services in terms of mileage and convenience especially to attract the discretionary riders;
- Provision of Car/Van pool Incentives such as "Guaranteed Ride Home" Programs; and
- Expansion and Improvement of Pedestrian and Bicycle Facilities.

CHAPTER THREE

RESEARCH APPROACH AND METHODOLOGY

3.1 Introduction

This chapter presents a detailed procedure for the design of the research; collection of primary and secondary data required for the study as well as their analysis is explained in the chapter. This procedure is organized and presented as a sequence of steps and techniques to achieve the objectives proposed in the study.

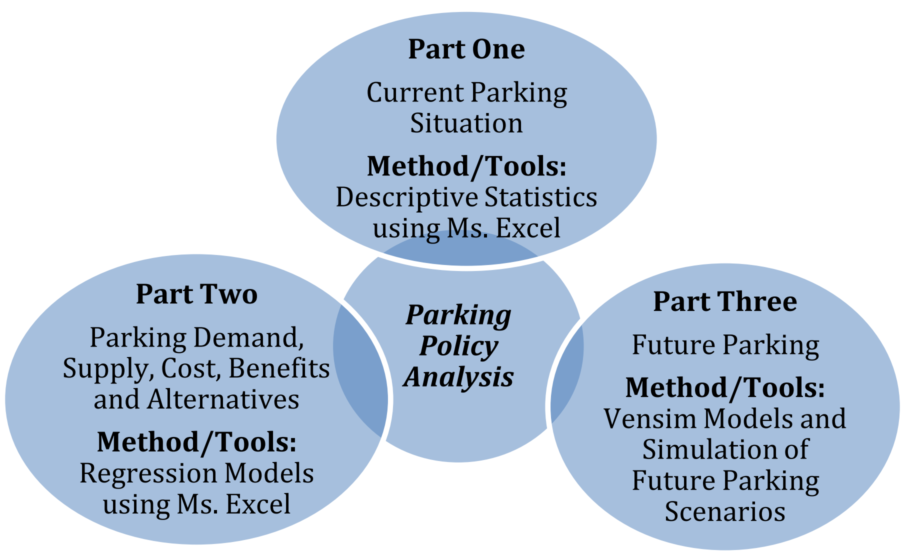
As stated earlier, the final outcome of the investigation was to determine whether the cost of satisfying parking demand will exceed its benefits. The methodology here was to extrapolate past and future demand trends by using the current situation. Thus, the sequence here was more of a "current-past-future" instead of the usual "past-current-future." The absence of some parking data necessitated the choice of this sequence. Hence for instance, parking estimates such as the presence ratio[8] from the 2002/2003 to 2010/2011 academic year could only be assumed to be the same as the year in which the parking occupancy survey for this study was conducted (2011/2012).

The Chapters 4,5 and 6 of this report have been dedicated to explaining each of these issues: current parking situation; parking demand, supply cost and benefit relationships based on previous academic years' data; and future parking policy analysis using a mathematical model. Figure 3.1 was developed to conceptualize the process for analyzing the results for the study. First, the current parking situation was determined to help

[8] The number of a particular user group present at the peak hour/period

estimate parking demand parameters such as the presence and driving ratios. Using these parameters, the next step was to estimate past parking demands for previous academic years (2002/2003 to 2010/2011). The cost and benefits of parking demand and supply for these previous years were then determined to test the hypothesis and also determine price subsidization, either on the part of the University or the parking users. Bearing in mind the dynamics of demand, supply, cost and benefits of previous academic years, the last step was to model the above variables to simulate future parking situations. The Vensim PLE software was used to generate the parking model for demand, supply, cost and benefits and it was also used to simulate scenarios of future behavior.

Figure 3.1: Study Parts and Methods



Source: Author's Construct, 2012

3.2 Research Design

The study followed a case study approach with both quantitative and qualitative analysis. The case study allowed for a detailed and contextual analysis of campus parking as a contemporary phenomenon in sustainable urban transport provision in the United States. Quantitative data were analyzed (see parking occupancy survey instruments in Appendices 1, 2a and 2b) and further explained using qualitative information from the interview with MSU Parking and Facilities Director (see Interview Guide in Appendix 3) and literature review.

As a research design, the case study approach has room for the modification and combination of a range of research techniques and methods. Although Minnesota State University Mankato was used as the case for this study, other cases of the same research problem can be studied by adapting this research methodology. This permits knowledge and data to be accumulated and used for comparison and a more refined parking model can be developed as more campuses are involved.

3.3 The Research Process

The approach adopted in conducting this study involved five interconnected research. These stages are explained below and presented in Figure 3.2.

❖ ***Synopsis Preparation***: A synopsis of the study was prepared and presented. The synopsis included: an introduction to the study; the research problem of parking on campuses; research statement/hypothesis, goal and questions; operational definitions; and the study's organization.

❖ ***Literature Review**:* Secondary data were reviewed from relevant books, working papers, published documents and reports from international organizations, institutional documents and figures from the Parking and Facilities Management Office and the Institutional Research, Planning and Assessment in MSU, Mankato. This review allowed the researcher to know the state of the problem, the approaches followed by other authors as well as information generated from different sources.

❖ ***Tools Design for Data Collection:*** An off-street parking survey and an on-street occupancy and turnover survey were designed. An interview guide for the University's Parking and Facilities Management Director was also designed. Table 3.1 shows the data collected, tools used in the collection and the relevance of each to the study.

Table 3.1: Data, Source and Relevance to the Study

Data	Source	Relevance
Parking Facilities and Permit Groups, Number of Spaces, Prices, Cost and Revenue.	a. Parking and Facilities Management Office b. Campus Hub in MSU.	Useful in: a. profiling and selecting the type, number and locations of parking facilities to be surveyed; b. calculating the parking cost and benefits on campus.
Number of students, faculty and staff who purchase any of the parking permits for fall semesters from 2011/2012 to 199/2000 academic years.	a. Parking and Facilities Management Office. b. Campus Hub in MSU.	Useful in determining parking: a. Presence ratios/factors; and b. Driving ratios/factors.
Number of Students, Faculty and Staff for the Fall semesters from 2011/2012 to 199/2000 academic years.	Institutional Research, Planning and Assessment in MSU, Mankato.	Useful in computing: a. driving ratios of users; and b. relation between demand ratios and number of users.
Number of occupied spaces on the selected parking lots from 8am to 5pm.	Primary data from the field survey	Used in determining the: a. Presence Ratios; b. Peak Period and Occupancy levels; and c. Excess Parking.
Transit data	Greater Mankato Transit Redesign Study Report	Used in determining the means of transportation to campus by various users.
Parking Issues on Campus	Interview with the Director of Parking and Facilities and another member of MSU Parking Committee	Relevant in understanding and assigning reasons to the qualitative data obtained.

Source: Author's Construct, 2012

- ***Field Work/Survey:*** The type and location of parking lots to be surveyed were determined purposefully to make sure that the major permit groups were included in the survey. The number of parking spaces to be surveyed was also determined so that not less than 70% of the total number of parking spaces available in each permit group was surveyed. Since the nature of the study was to develop a model, capturing all the parking spaces will not only generate unnecessary data, it also had the possibility of leading to "entropy" in the survey data, due to the extra time needed for sorting out the data.

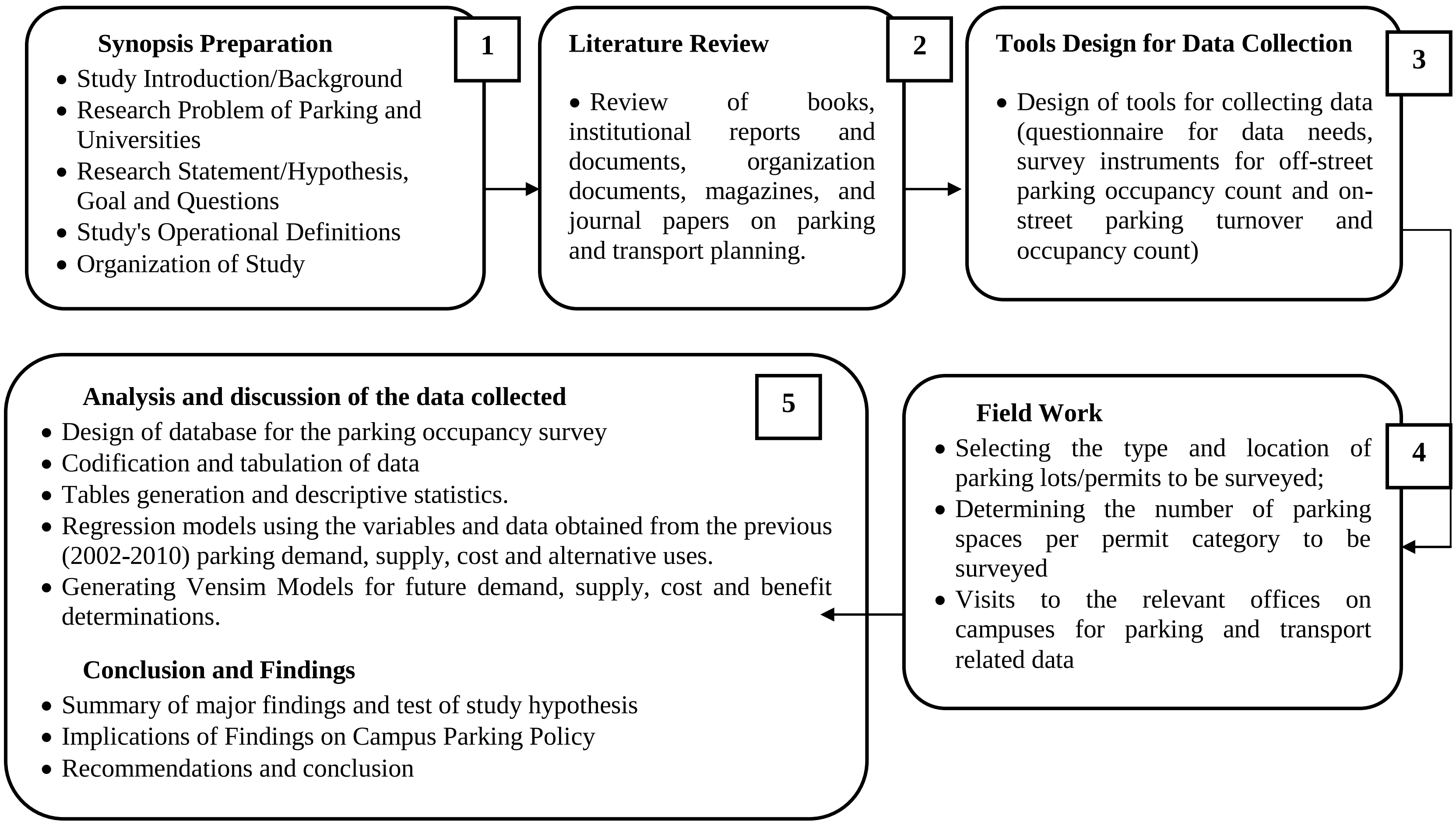
An off-street parking occupancy survey was conducted for two days in the fall semester of 2012. A day was also devoted to conducting on-street occupancy and turnover counts. Interviews were also conducted with the Parking and Facilities Management Office, Institutional Research, Planning and Assessment, and the Campus Hub in MSU. A total of one month and two weeks was used in gathering data. As and when clarification and validation of data were required, additional visits were made to these offices in the course of the study.

- ***Data Analysis:*** This was a three-stage process. The first stage, detailed in Chapter 4 of this report, analyzed and discussed the current parking situation in MSU using the parking occupancy survey. The second part, discussed in Chapter 5, was concerned with parking demand, supply, cost and benefits relationships. By considering the 2002/2003 to 20010/2011 academic years, this part of the study was used to understand the behavior of parking demand, supply, cost and benefits.

Using the relationships uncovered in Chapter 5, Chapter 6 created a mathematical model of parking demand, supply, cost, benefits by using the Vensim PLE software. The model was then used to simulate MSU's parking situation for a 5 year period based on a new parking policy introduced in 2012.

- ***Presentation and Reporting**:* With the use of Microsoft Excel, an analysis of the major results from the field work was developed using descriptive statistical tools such as percentages, averages and statistical functions. The descriptive analysis part of the study was summarized in tables and illustrated through charts.

Figure 3.2. Research Framework



Source: Author's Construct, April, 2012

3.4 Number of Sample Parking Spaces for the Study

The survey considered four main parking user groups on campus: resident students, non-resident students, faculty/staff and visitors. Off-campus students (those who take all their classes outside MSU's Mankato campus as well as all online students) were excluded from this study since their probability of coming to campus even within the semester is negligible. Also, in all instances, Fall population figures were used.

The total parking spaces on campus is about 4,939 spaces/stalls (both on-street and off-street parking) according to the MSU Lot Maintenance Plan, prepared in 2011. A total of 4,544 spaces (on and off street parking) are available to the University including the visitors' lot, the free lot, and the permit-based lots (gold, orange, light and dark green, purple and brown[9]). The study limited its scope to the following off-street parking spaces (see Table 3.2 and Figure 3.3).

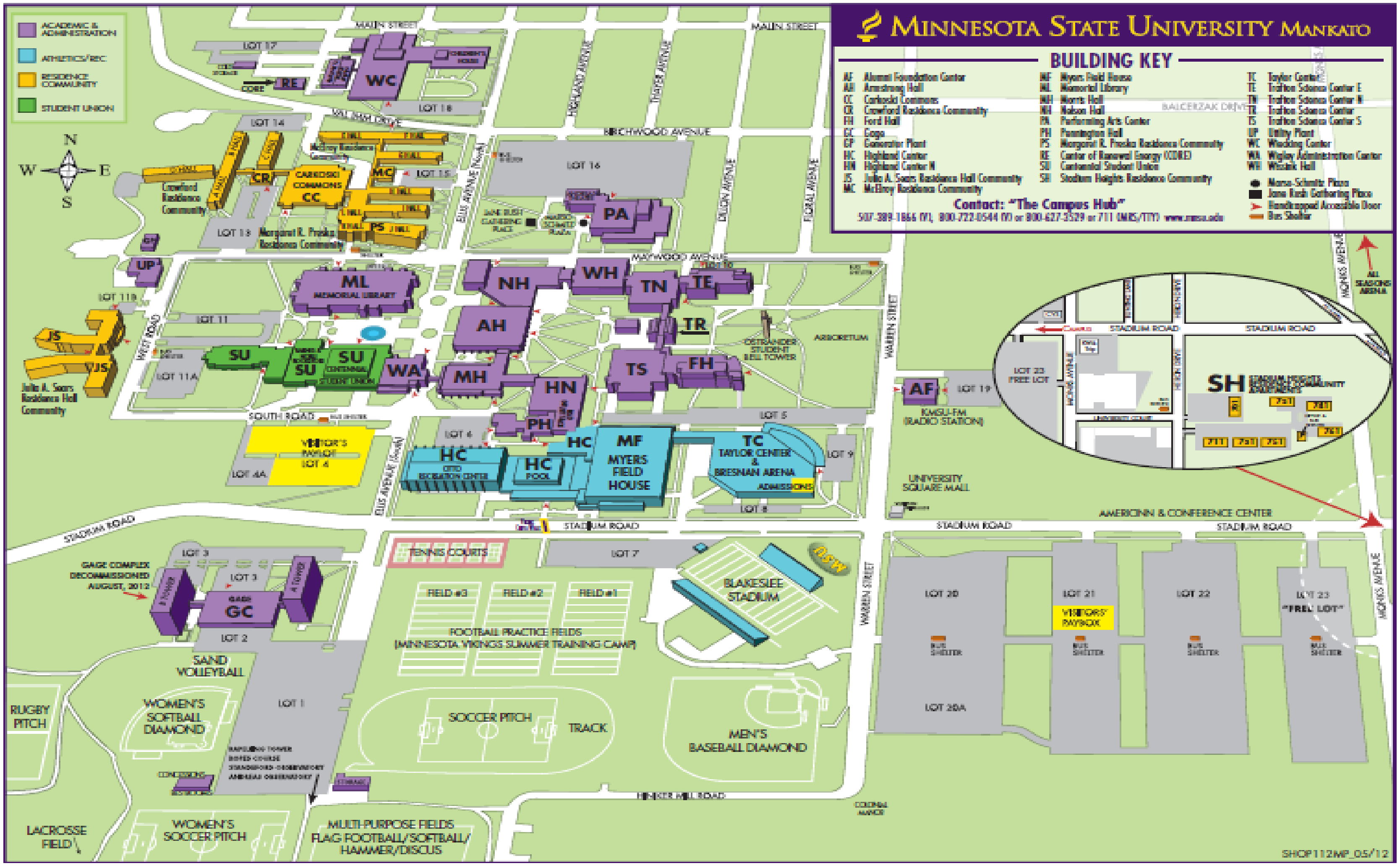
Table 3.2: Parking Facilities Surveyed

Permit Category	**Total Number of Spaces**	**Number of off-street Spaces Surveyed**	**Name of Lots of Surveyed**
Gold	943	677	4a; 5; 6; 7; 8; 11; 11a; and 16.
Orange	563	563	21 South; 22 North and South
Purple	618	521	20 and 21 North
Light Green	1213	922	1 and 16
Dark Green	560	494	20a and 21 South
Visitors Lot	211	211	Lot 4
Free Lot	436	436	23 North and South
Total	**4,544**	**3,824**	------------

Source: Author's Construct, 2012

[9] Brown Parking was not considered since it is leased and permits are only issued to the University Square Village tenants by University Square Village tenants, not MSU.

Figure 3.3: Campus Map with Location of Parking Facilities, Minnesota State University, Mankato



Source: Parking and Facilities Management website, Minnesota State University, Mankato; 2012.

3.5 Determining Parking Demand, Supply, Cost, Benefits and Alternative Transport Users

3.5.1 Parking Demand

The parking demand (D) for the campus users was determined by first calculating their demand ratios (DR) and multiplying their ratios by total number in that user group (N). To do this, as explained earlier, the demand ratio of each campus parking user is the product of its presence ratio and driving ratio.

For instance, demand ratio for resident students (DR_{rs})

= driving ratio of resident students (dR_{rs}) × presence ratio of resident students (P_{rs})

So, $DR_{rs} = dR_{rs} \times P_{rs}$ .... ***Equation 1***

After determining demand ratios for each of these users from 2010/2011 to 2002/2003 academic years (see Table 3.3), the number of parking spaces in demand was computed using the demand ratios. A multivariate linear regression analysis was then calculated to determine the relationship between the total parking demand, the number of people in each user group and the average price paid per parking space by each user group.

Table 3.3: Parking Demand Ratios for Campus Parking User Groups

Academic Years	**Students (Resident Students)**	**Students (Non-Resident Students)**	**Faculty/Staff**
2010/2011	0.57	0.13	0.54
2009/2010	0.57	0.13	0.54
2008/2009	0.56	0.13	0.51
2007/2008	0.55	0.13	0.53
2006/2007	0.54	0.13	0.54
2005/2006	0.54	0.13	0.55
2004/2005	0.55	0.13	0.56
2003/2004	0.55	0.13	0.58
2002/2003	0.55	0.13	0.59

Source: Author's Construct, 2012

❖ *Determining the Driving Ratios/Factors for Parking Users*

As explained in the operational definition section, by knowing the number of each user group who purchase any of the parking permits, the driving ratio for each user group was expressed as the ratio of the number of people in that user group who purchase any of the parking permit to the total number of people in that user group. Table 3.4 shows the driving ratios for each of the user groups for the academic years under consideration.

Therefore, driving ratio for resident students (dR_{rs}) =

No. of resident students who purchase permits (RS_p) / Total No. of resident students (N_{rs})

$dR_{rs} = RS_p / N_{rs}$ ....***Equation 2***

Data on the number of people who purchased any of the permits from the 2007/2008 to 2002/2003 academic years were not available. Therefore by using the data of the number of people in each user group versus the number of permits purchased from the 2011/2012 to 2008/2009 academic year, regression analysis was used to estimate the number of people who purchase permits for each user group (see Tables in Appendices 4,5, and 6).

Table 3.4: Driving Ratios for Campus Parking User Groups

Academic Years	Student		
	Resident Students	Non-Resident Students	Faculty/Staff
2010/2011	0.73	0.32	0.92
2009/2010	0.74	0.31	0.93
2008/2009	0.72	0.30	0.88
2007/2008	0.71	0.32	0.90
2006/2007	0.70	0.32	0.93
2005/2006	0.70	0.32	0.95
2004/2005	0.71	0.32	0.96
2003/2004	0.71	0.31	0.99
2002/2003	0.71	0.30	1.00

Source: Author's Construct, 2012

❖ *Determining the Presence Ratios/Factors*

The presence factor measures the portion of a user group who park during the peak hour. The difficulty in measuring this variable lies in knowing which of the parked vehicles at peak period belongs to either resident or non-resident students or faculty/staff. But the issue can further be simplified to obtain a much closer estimation of who is present by first finding the number of each permit category present during peak hour. Based on the parking occupancy survey, Table 3.5 presents the percentage of each permit category present at peak hour. The percentages were used to calculate the total number present.

Table 3.5: Presence Ratios for Campus Parking User Groups

Parking Permit Categories	**% Present**	**Total Number**
Gold	0.75	708
Orange	0.76	428
Purple	0.78	482
Dark Green	1	560
Light Green	0.85	1030
Free Lot	1	436

Source: Author's Construct, 2012

Knowing the number of permit categories present at peak period, what is left is to find the proportion of the user groups constituting that permit group. With the exception of the free lot[10], the remainder are much easier to estimate since MSU's Parking and Facilities Management office has data to show how many students (resident and non-resident) and faculty/staff purchase each of the permits. By using the proportions in Table 3.6, Table 3.7 presents the number of each permit category present at the peak hour and the proportion of users in that category.

Table 3.6: Proportion of Parking Users in the Parking User Groups

Parking Permit Categories	Students (Resident Students)	Students (Non-Resident Students)	Faculty/Staff
Gold	0.00	0.20	0.80
Orange	0.00	0.79	0.21
Purple	0.00	0.80	0.20
Dark Green	1.00	0.00	0.00
Light Green	1.00	0.00	0.00
Free Lot*	0.14	0.85	0.02

Source: Author's Construct, 2012

[10] The proportion of user groups in the free lot was determined by finding the excess number of people within each group who did not buy any of the permits. Excess for faculty (158), non-resident students (8211); and resident students (1333). Their proportion was then determined as 0.02 for faculty, 0.85 for non-resident students, and 0.14 for resident students. The number of each of these users present at the free lot during the peak hour was determined using these proportions.

Table 3.7: Number of Parking Users Present at Peak Period

Users	Number Present at Peak Hour						
	Gold	Orange	Purple	Dark Green	Light Green	Free Lot	TOTAL
Students (Resident Students)	0	0	0	560	1030	61	1651
Students (Non-Resident Students)	142	338	386	0	0	371	1236
Faculty/Staff	566	90	96	0	0	9	761

Source: Author's Construct, 2012

Thus, the presence ratio for resident students (P_{rs}) for instance was calculated for as follows;

= No. of resident students present at peak hour/period (PH_{rs}) / No. of resident students who purchase permits (RS_p)

So, $P_{rs} = PH_{rs} / RS_p$ ....***Equation 3.***

Using this same process, the presence ratio for non-resident and faculty/staff users were computed and summarized in Table 3.8.

Table 3.8: Presence Ratios for Campus Parking Users

Campus Parking Users	**Presence Factor**
Students (Resident Students)	**0.77**
Students (Non-Resident Students)	**0.42**
Faculty/Staff	**0.58**

Source: Author's Construct, 2012

❖ *Determining the Demand Ratio (DR) using the Driving Ratio (dR) Presence Ratio (P)*

Substituting Equations 2 and 3 into 1, the demand ratio for resident students then becomes

$$DR_{rs} = (RS_p / N_{rs}) * (PH_{rs} / RS_{p)}$$ ....***Equation 4***

Equation 4 is therefore simplified as;

$$DR_{rs} = N_{rs} / PH_{rs}$$ ....***Equation 4a***

Equation 4a means that the demand ratio for resident students is the proportion of the number of resident students parked during the peak hour/period and the total number of resident students. This fits the earlier operational definition given for parking demand ratio, which is also referred to as the "Peak Permit Use". The demand ratios for the non-resident students and faculty/staff were determined using the same means.

3.5.2 Parking Supply

Since data are available on the number of parking spaces (supply) which have been in existence for the various semesters, parking supply for the years under study (presented in Appendix 7) did not require any calculation.

3.5.3 Parking Costs

The cost of parking was expressed in terms of three main variables; cost of land, construction, and annual OM cost. The cost of land on campus is the opportunity cost of renting that land for other purposes as well as the environmental loss as a result of destroying the vegetation cover and paving the surfaces. The land and construction cost (which forms the capital cost) were annualized at a rate of 3% for a total period of ten years. Table 3.9 summarizes the cost parameters. The results of parking cost per space obtained for each of the years represented the "break even" price for each parking space.

The formula for the annualizing was;

$$A = \frac{PV}{\frac{(1+i)^n - 1}{i(1+i)^n}} \quad \textbf{\textit{Equation 5.}}$$

where;

PV = present value or worth

i = interest rate

n = number of years

Table 3.9: Cost Parameters

Cost Parameters	MSU Campus	Notes
Average Size of parking space (square feet)	290	A parking lot (Lot 16) of size 190,289 sq ft with 657 parking spaces will mean a parking space will be about 290 sq ft.
Average Land Cost per parking space (square feet)[11]	$580*	The average price for 1sq ft of land around MSU campus area is $2. So a parking space of size 290sq ft will have a land cost of $580
Interest Rate	3%	Interest rate for long-term capital investments.
Years of Payments	10	Years of payments.
Average Days of Use Per Month	20	Typical number of days that parking space can be rented each month.
Construction Cost Per Space (curb and gutter, hard surface, lighting)	$2500	This is stated on MSU Parking and Transportation Services Website

Source: Author's Construct, 2012

[11] The average cost of land on campus is estimated to be in the range of $1-3 per square feet based on the land description; according to the Mankato Community Director, Paul Vogel. Here, an average of $2 was used for the cost analysis.

3.5.4 Parking Benefits

As already indicated, benefits in this discussion were expressed in terms of revenue. Again, the data on the annual revenue generated from parking was used in estimating the cost generated per parking space. The caveat here was that, since there are free lots, the revenue generated per parking space were done using only the paid parking spaces.

3.5.5 Transit and Alternative Transportation Users

Also referred to in this study as "parking substitutes," this involved the number of students (resident and non-resident) and the faculty/staff who used other transportation means to and/or from campus. Due to the existence of these substitutes, some parking users on campus might decide not to bring their vehicles to campus which might influence the demand for parking spaces on campus. Conversely, despite the existence of these substitutes, parking demand may increase or decrease if:

- users do not find the substitutes convenient (will result in an increase or no change in parking demand);
- price for parking is considered high by parking users (will cause a decrease in demand and increase in substitutes)
- price for parking although increasing, is still affordable to the users (will lead to an increase or no change in demand); and
- parking supply is limited, causing users to use these substitutes.

These alternatives included those who walked to campus or used bus, carpooling/car sharing, motorcycles and bicycles. Data for this section were retrieved from the database of the Greater Mankato Transit Redesign Study (URSI, 2011).

The alternatives for the resident students included bus, walking, motorcycles and bicycles, while that of non-resident students and faculty/staff included all of resident students' alternatives plus carpooling/sharing. Resident students have little use for carpooling except for occasional outings, so including that in the analysis was considered redundant.

3.5.6 Demand, Supply, Cost/Price and Alternative Users/Substitutes Relationship

To obtain a demand model, regression analysis was done on supply, cost/price per space and the number of alternative transportation users. This regression model was used to examine the past parking behavior of MSU. Thus, for each of the campus parking user groups, the parking demand from 2002/2003 to 2010/2011 academic year was regressed on the parking spaces available (supply), cost/price per space, and parking substitutes.

3.6 Modeling Future Parking Scenarios Using Vensim PLE

Knowing the parking behavior in the past is one thing but knowing the future trends is another. The regression models for the past demand was useful in understanding how certain variables interact in determining parking demand on campus. Based on this understanding, a diagrammatic view of parking demand variables, infused with equations, was developed using the Vensim PLE software. The resulting economic model was used to determine trends in parking demand for a discrete period in time, given specific scenarios. Using Euler integration, the model was set with a time step of 1 year for a total period of 5 years.

3.6.1 The Variables in the Parking Model

Vensim has several categorizations of variables, with each variable having its purpose. For the purpose of this model, understanding the dynamics of the model require a brief explanation of the specific variables used in this model. Vensim's reference manual (2010) helps in defining each of the following variables used in the model:

Levels (also known as state variables, accumulations and stocks): These determine the dynamic behavior of the model by generating change over time. They work by integration over time. Thus, the value of a level at a given time depends on its previous value as well as the previous values of other variables. In this model, the "levels" are Total Demand/Peak Use, Supply, and Price.

So,

$$levels_t = \int_0^T rates_t dt \quad \text{or} \quad \frac{d}{dt} levels_t = rates_t$$

..............................***Equation 6***

Rates: Rates are also called flows and are directly responsible for changing levels. They are said to be the thought of as an auxiliary used in changing a Level. Thus, any auxiliary used in changing a Level can be seen as a rate. A major distinction here is that rates are determined by auxiliaries and other variables. The rates in this model are Demand, Non-Parking Users, Change in Price, Change in Supply, and Optimum Supply.

Constants: Constants do not change with time. These were the initial values (demand, supply, and price), initial targets (price and supply), optimum supply level, demand and supply elasticities, and the initial ratios (permit users, number present at peak use and non-parking users).

Auxiliary: These are computed from Levels, Constants, Data, and other Auxiliaries. Auxiliary variables have no memory, and their current values are independent of the values of variables at previous times. All the remaining variables are auxiliaries.

3.6.2 Simulating the Model

Having developed this model, three simulations were done (as analyzed in Chapter 6 of the report) to determine the future parking scenario based on MSU's new parking policy in 2012.

3.6.3 Limitations of the Model

The model assumes that the trend in demand will increase even when actual demand decreases, for example after being affected by price increases. This might not be the case since demand can decrease perpetually without ever increasing, for example if campus users decide to switch to transit due to service improvements, fuel price increases and other factors.

CHAPTER FOUR

MSU's CURRENT PARKING SITUATION

4.1 Introduction - Parking Occupancy, Peak Period and Prices

In context, parking occupancy studies provides an indication of how many spaces are demanded as against what is supplied. The peak hour/time/period is therefore a fair means to determine the maximum number of parking spaces that parking patrons demand. When parking demand is at its highest, two key pieces of information are extracted for parking decisions: when (the specific hour of the day) the highest demand is recorded, and the quantity of demand at that peak time. The parking decision then made from these two key findings relates to the question of "Do we have enough parking spaces (supply) to meet the demand at the peak time?" A more refined parking decision will then apply the industrial standard of setting parking supply to 85% of peak demand.

An outcome that shows demand is met with either an excess or shortage of supply at the 85% occupancy gives an indication of either faulting pricing (as highlighted by Shoup 2008) [12]or a parking supply policy which either relies on a faulty parking requirements standards or does not have one at all. If supply is in excess at the 85% occupancy, the implication is that excess cost is incurred as a result of building and maintaining excess parking spaces which are not in use. Conversely, shortage of supply implies the under maximization of parking benefits since parking patrons are turned away due to limited

[12] Shoup (2008, p. 137) explains faulty pricing when he avers that "When the price is not right, either too many spaces will be empty (the price is too high) or shortages will appear (the price is too low)

parking spaces, and could result in the creation of illegal parking spots by the patrons, and increase in parking offenses.

The excess or shortage of parking spaces is expressed at a given time period, which is the peak time/period. However, people park throughout the day at the designated parking areas (Litman, 2012b), and hence the issue of excess or shortage does not necessarily mean demolishing excess spaces or building new spaces. The most pragmatic step is to consider "pricing" or "performance-based pricing" of these spaces so that demand and supply at specific time periods will be balanced by pricing (Shoup, 2008; Tumlin, 2012). The issue of performance-based pricing is explored further at later stages of this research. This section is only tailored to discuss the existing MSU parking situation with respect to occupancy, peak period and prices, based on survey conducted and pricing documents reviewed.

4. 2 MSU Surface Parking Situation - The Big Picture

In totality, MSU's parking occupancy levels (indicated in Figure 4.1) ranges from 50% to 82% within a 9 hour period of a school day. This range increases to 60% and 96% respectively when computed in relation to the 85% occupancy level set. In other words, within a 9 hour period (8am to 5pm) of a school day in MSU, at an 85% occupancy level, as high as 45% (1,326) and as low as 10% (121) of parking spaces (based on the total number of surveyed parking lots) are empty[13]. In fact, when compared with the overall

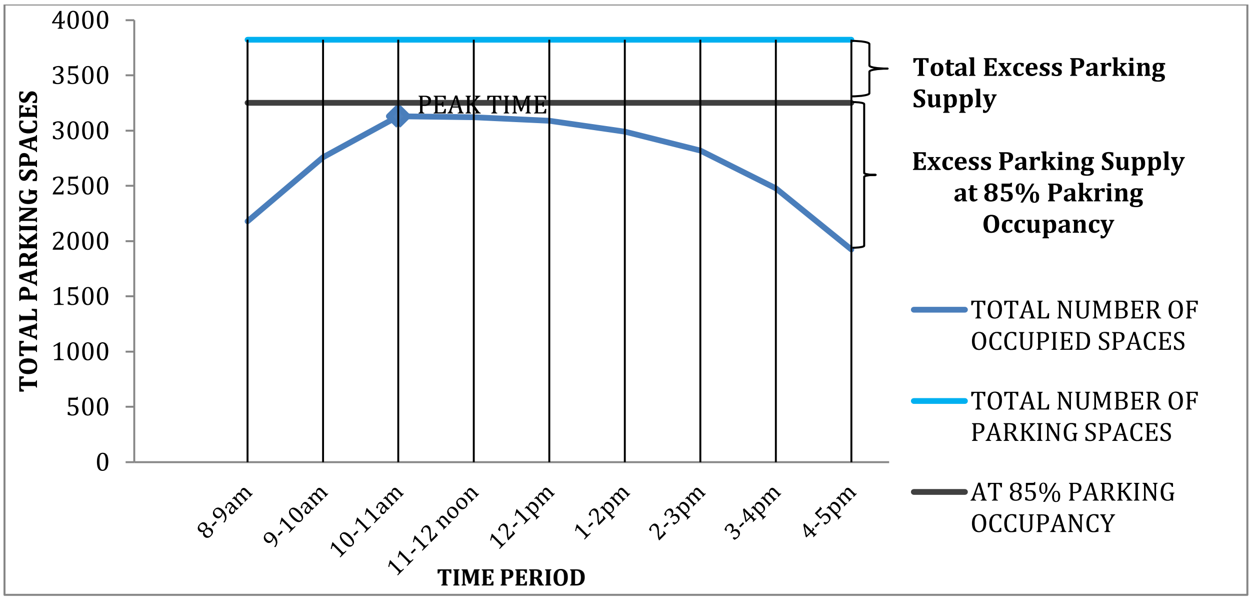
[13] And yet, people have difficulty locating empty spaces to park. Because, space like any resource, if not well distributed, can be scarce even in its abundance.

parking supply, even at the peak period, the vacancy rate is as high as 18% of the total parking supply.

In effect, there are more than 18% vacant spots scattered all over MSU campus at the peak period of a school day, yet people find it difficult to find parking spaces. In terms of cost and benefits, each vacant space represent a unit cost to campus since expenditures were made in the construction of each parking space while expenditures are still being made to maintain and operate each space. It also offers opportunity cost to campus since each unit of vacant space represents a land area that could have been used for something else. On the issue of benefits, a unit of vacant space represents a loss in parking revenue to campus. A more detailed analysis of cost and benefit related to the vacancy/occupancy levels will be discussed subsequently in the study.

Figure 4.1 also shows that between the hours of 10 a.m. (peak time) to about 3 p.m., parking occupancy is relatively constant and exceeds 65% occupancy level. The average percent change in the decrease of occupancy is as low as 0.3% within this period. In a 2005 downtown parking study for the city of Spokane, the authors asserted that a parking occupancy is consistent with patterns of commuter parking typical of off-street use in urban areas when the use of parking facilities remains constant between the hours of 10:30am and 3:30pm, and exceeds 60% occupancy level. Realizing that MSU's parking pattern is consistent with other empirical studies of parking characteristics in urban areas, it supports the generalization of findings from this research to other urban areas.

Figure 4.1: Peak Parking Period and Excess Parking Supply for All Parking Facilities Surveyed



Source: MSU Parking Survey, 2012.

Photo 1: A view of MSU's largest surface parking facility (around 2000 parking spaces); occupying around 13acres of land

Credit: Taken by Author during field survey on April 23, 2012

4.3 Occupancy and Peak Hour by Parking Permit Categories

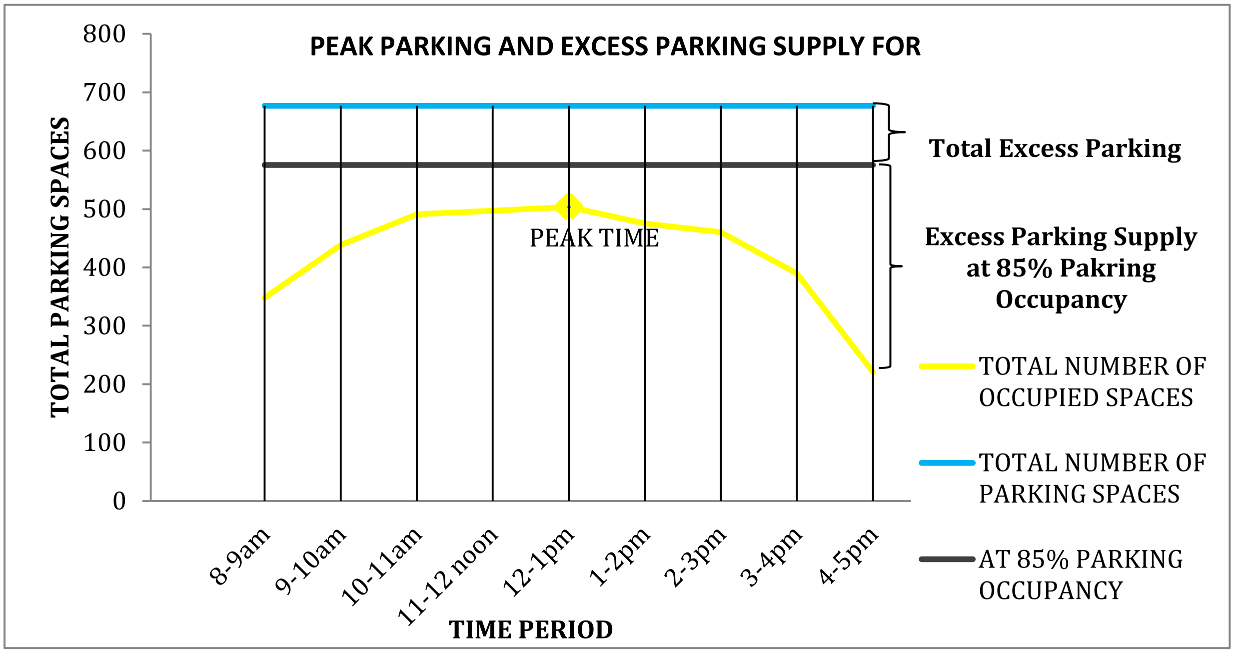
4.3.1 Gold Permits

Strategically located in close proximity to buildings and at the core of campus, the gold permit offers the ideal permit location for most if not all parking users on campus. It is of little surprise that gold permits in MSU can only be purchased if a person's application is selected as part of the lottery system used in selecting gold permit holders for each academic year. The mere fact that applications for gold permit rarely changes irrespective of increase in prices, creates an initial impression that gold permit spaces will be full most of the time or at least at the peak time.

As Figure 4.2 shows, the vacancy rate of about 12.5% is almost constant from 10am to about 2pm. Such a vacancy rate calls for a second look at the pricing and designation of parking locations on campus. If a prime parking location, sited close to buildings and at the core of campus, cannot achieve less than 5% vacancy rate at the 85% occupancy level for even its peak time, then there is a need for a policy intervention.

Within such peak hours however, people may be "hunting" for vacant parking spaces on campus. Even if they are aware that such favorable vacant spaces exist during these hours, they cannot still park there. This is because these spaces are allocated before the semester starts. Thus, if a person is willing and able to pay for such favorable spaces at their point of need, they cannot have it, meaning revenue loss and the creation of unnecessary inconvenience for parking users. Will it then be economically prudent to have a system where people can have and pay for parking spaces, when they want them and for how long they want them? Will such a system be convenient for campuses to meet their parking demand without making cost exceed benefits?

Figure 4.2: Peak Parking Period and Excess Parking Supply for Gold Permits

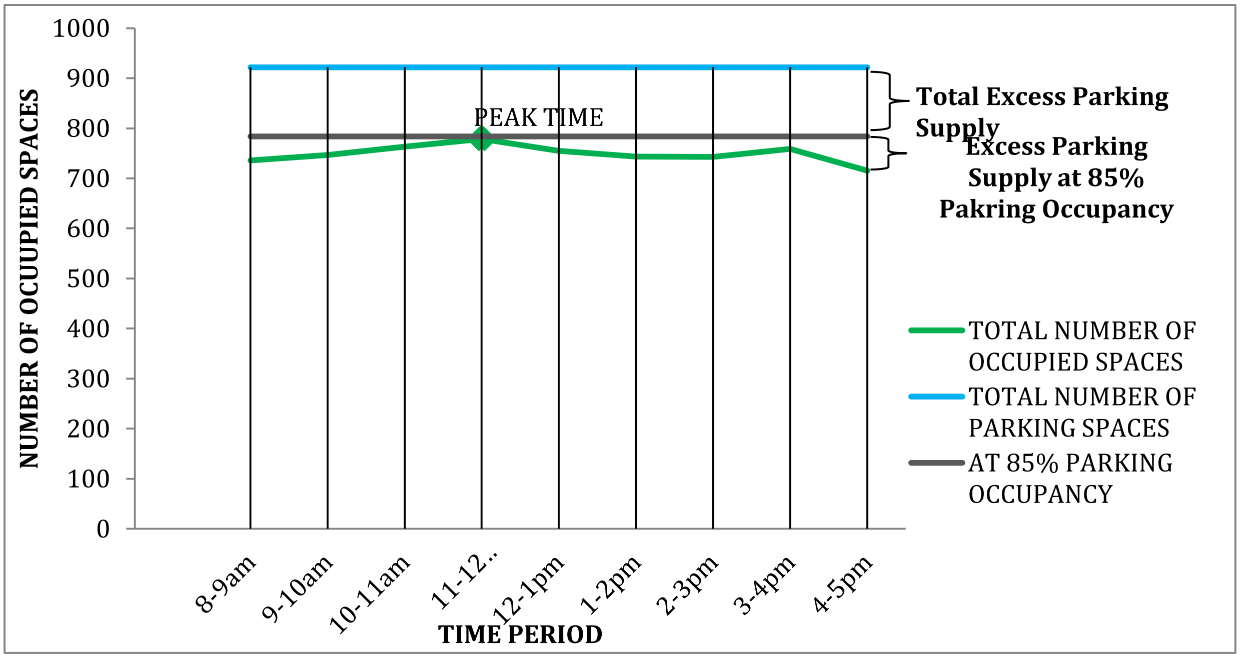


Source: MSU Parking Survey, 2012.

4.3.2 Light Green Permits

Designated mainly for residence students, the light green permit group at its peak period (11a.m. -12 p.m.) achieves an almost 100% occupancy (meaning 0% vacancy) at the 85% occupancy level. As shown in Figure 4.3, the highest vacancy rate that this permit group records is 8.6% which is less than the lowest vacancy rate recorded by the gold permit at its peak period. Again, the relatively stable level of the occupancy level shown by the graph depicts that this permit is used by people who barely move their vehicles. This is supported by the fact that at the 4-5pm period where most classes are done on campus, the decrease in the number of occupied spaces is minimal.

Figure 4.3: Peak Parking Period and Excess Parking Supply for Light Green Permit



Source: MSU Parking Survey, 2012.

This picture painted by the light green permit group although pleasant does not yet depict optimum use of parking space and hence land on campus. The total parking space allocated for this permit category (using lot 1 and 16) during the survey was 922 spaces. At the 85% occupancy level, there is an excess of 138 spaces. Given that an average area for a parking space in this permit category is 286 square ft, the 138 spaces makes up a total of 39,481square feet [14] of land. Issues such as the alternative uses that the land could have been put to, cost of constructing and maintaining these excess spaces, and the economic losses for the non-utilization of these spaces are all plausible concerns that could be raised and addressed in MSU's parking policies.

[14] In January of 2012, NYU planned to use about 40,000square ft. of land to create a public parkland and open space. This proposed land area is almost the same as the 39, 481 square ft that MSU's unused parking spaces for the light green permits occupy.

4.3.3 Dark Green Permits

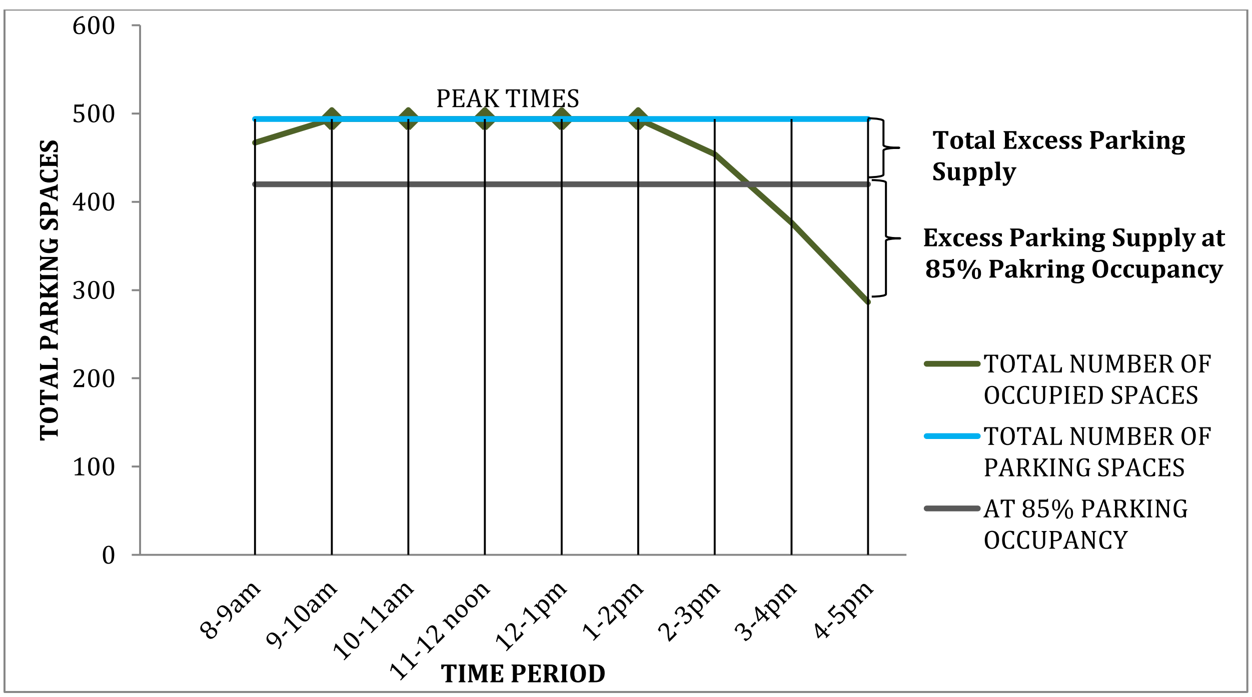
Presented in Figure 4.4 is a parking permit category (dark green) which exhibits a more optimum use of parking spaces, compared with the gold and light green categories. The dark green permit, which is a discount residence hall parking located farther away from campus than would have been expected for a permit category which is to serve residence hall students. This notwithstanding, during the peak periods from 10 a.m to 2 p.m. its occupancy exceeds the 85% occupancy level. In fact, there is no space left at the peak periods. Demand is in the negatives at these periods when measured at the 85% occupancy level.

Due to the behavior of this permit group, the authorities designated an overflow area in Lot 21 South to absorb the excesses. Shortage of supply of these parking spaces, especially at the 85% occupancy level means high demand. This means that users of this permit category will have to spend time and fuel within the parking lot area looking for a space to park. What happens then if they don't find the space? It is of no surprise that a total of 100 spaces have been proposed to be added on to the existing Dark Green permits spaces. However, contrary to this policy of adding more spaces, Shoup (2008), Litman (2011), and Tumlin (2012) believe that a prudent parking policy will rather try to balance demand and supply by adjusting "prices" to help achieve the 85% occupancy level.

The long peak period is also an indication that this permit is used by people who require longer parking duration which is a characteristic of residential students. Again, the sharp decline in the number of occupied spaces also suggest that these people, although residential students, often move out of campus at later hours in the day and hence do not necessarily need to spend much money purchasing the light green permits.

Cost of parking, convenience in terms of easy accessibility to hall of residences and other areas on campus and security for both driver and vehicle are major considerations for students. The dark green permit has closed-circuit cameras and provides free passes for students who park in this area for them to use the bus services to their residence halls and to other areas on campus. The cost for parking in this area is discounted as compared to the cost of parking at the light green spaces which are much closer to the residence halls, classrooms and other areas on campus. These services associated with this permit group make it of much value to the residence hall students.

Figure 4.4: Peak Parking Period and Excess Parking Supply for Dark Green Permit

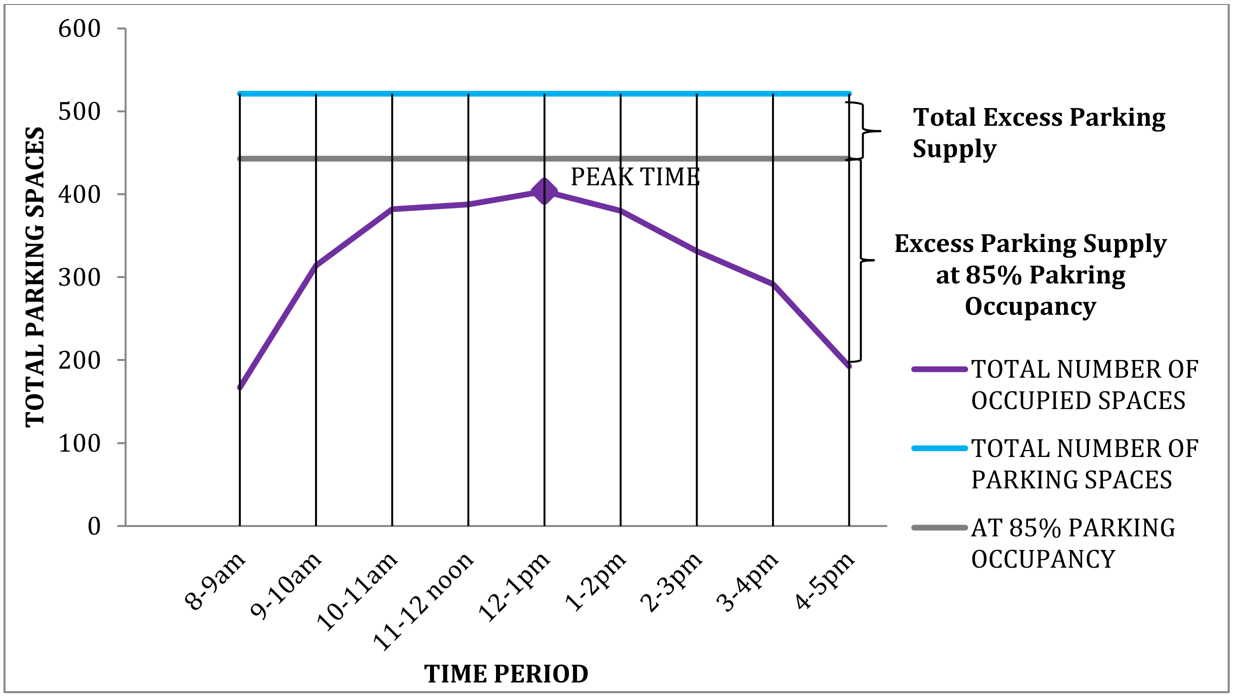


Source: MSU Parking Survey, 2012.

4.3.4 Purple Permits

At the 12-1 p.m. peak period, parking occupancy for purple permit (see Figure 4.5) is similar to that of the gold permits. At the 85% occupancy level, the vacancy rate can be as low as 9% at the peak period and 62% at the off-peak period. However, given the fact that this permit category is not located close to the classrooms and other major areas on campus, the interpretation of its performance is not the same as that of the gold. The most important issue here is in the excess parking spaces. With more than 100 parking spaces left even at the peak hour, the significant question to ask is "are we being prudent in the use of our land on campus?" The study will explore possible answers to this question when it focuses on the costs and benefits of our existing and future parking policies on campus.

Figure 4.5: Peak Parking Period and Excess Parking Supply for Purple Permit

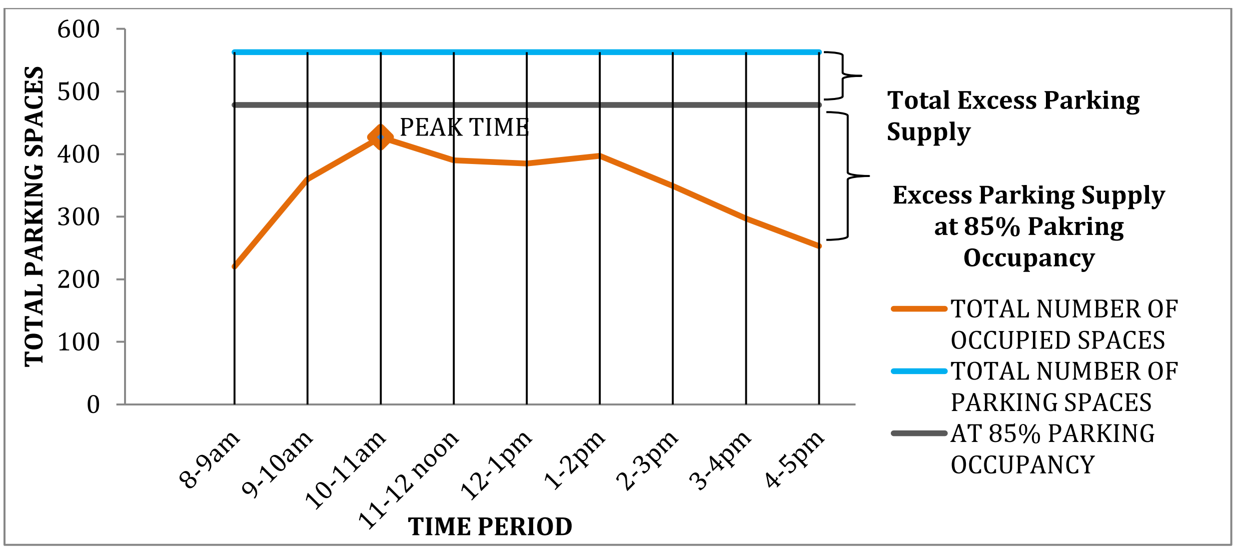


Source: MSU Parking Survey, 2012.

4.3.5 Orange Permits

The situation with that of orange permit (shown in Figure 4.6) is not much different from that of purple, which are also in close proximity to each other. The issue of excess space even at the peak period is also manifested with this permit group. The only thing that separates these two permits is their price. For the 2011/2012 academic year, the price per space was $134 and $96 for the purple and orange respectively. Hence, it is not surprising that the orange permit group reaches its peak earlier than the purple. It is also worth noting that even though it reaches its peak around 10-11 a.m. period, it declines and rises to another peak within the 1-2 p.m. period, although the second peak is lower than the first. This is a characteristic of users who must be on campus early, leave and come again. Even though the visitor lots could be an alternative to the orange permit for these users, the former's price is computed marginally (cost per hour) and hence makes it more costly than the latter, which has an average price (semester and year prices).

Figure 4.6: Peak Parking Period and Excess Parking Supply for Orange Permit



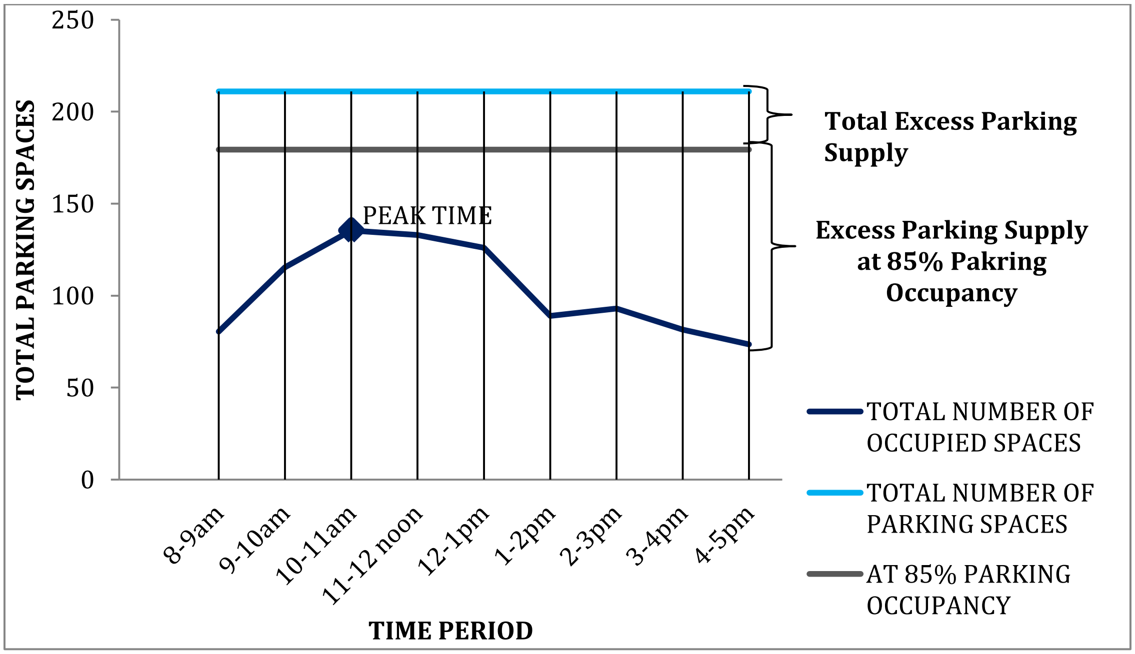
Source: MSU Parking Survey, 2012.

4.3.6 The Visitors' Lot

Located at the area popularly known as the "sunken" lot area, the visitors lot offers much more convenience to its users in terms of proximity to the most important location on campus, which is the Centennial Students' Union (CSU) building. Activities on campus converge at this point especially as it serves as a major landmark and the focus for all transit routes on campus. The behavior of its occupancy level as portrayed in Figure 4.7, with its rise and fall at shorter intervals, is very typical of a user group who need parking spaces for shorter time periods. Since the cost of using this space is calculated based on the parking duration, campus visitors are the most suited user group for this permit category.

The most compelling reason for a vacancy rate of 25% even at peak periods can be closely linked to the price charged for space. The existing situation indicates loss to the university since not less than 25% of the visitor parking spaces are not used, and yet money is spent operating and maintaining them. Since this area is close to campus, an alternative would have been to convert the excess parking spaces to another parking permit category whose users need the space for shorter durations like the "dark green" or "orange" permit. Better yet, the land could be used for an open space project which could possibly help achieve the "Green Campus" agenda.

Figure 4.7: Peak Parking Period and Excess Parking Supply for Visitors Lot



Source: MSU Parking Survey, 2012.

Photo 2: About one-third of the visitors' parking lot (Lot 4) empty at peak period (10-11am).

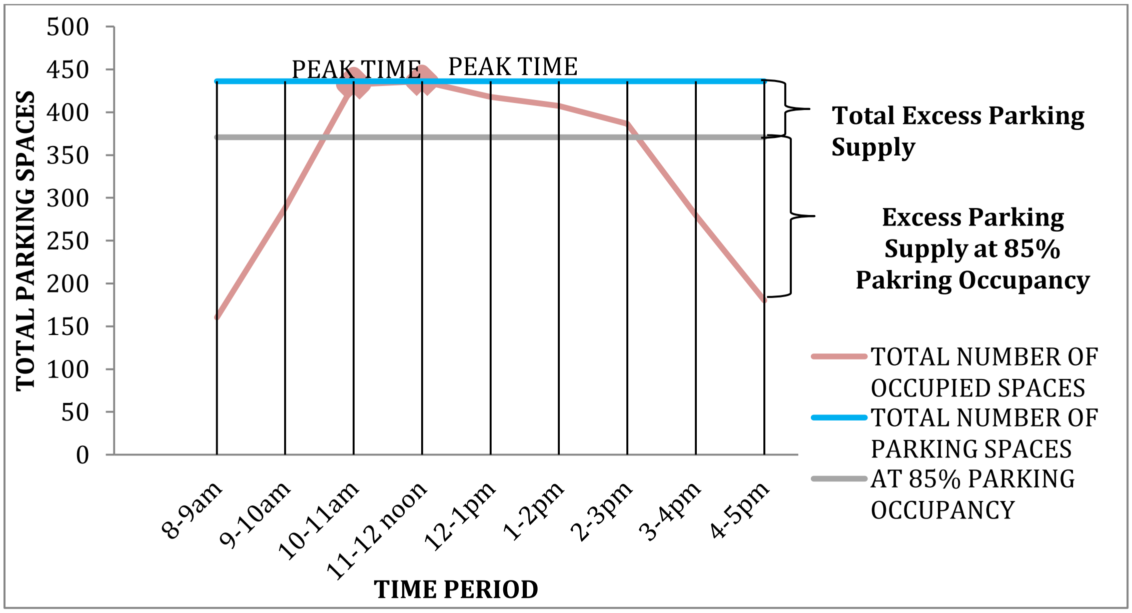
Credit: Taken by Author during field survey on April 23, 2012

4.3.7 The Free Lot

A typical characteristic of a free and limited commodity (air being a possible exception) lies in its shortage as demand increases. Occupancy at the free lot, depicted in Figure 4.8, rises steeply above the 85% occupancy level, attains double peak periods (10-11a.m. and 11-12 p.m.), maintains a stable occupancy above the 85% occupancy until a 3 p.m. and then falls steeply. From a theoretical point of view, when compared with the dark green, orange and purple categories which are all located in close proximity to each other, with the exception of the dark green permit, the free lot is expected to reach its peak faster, exceed the 85% occupancy and maintain a relatively high occupancy longer.

The dark green is for residential students so vehicles will always be packed earlier and those students who leave campus the previous night will come to campus earlier and prepare for classes. However, because the majority of campus users who use the free lot may not have permits, either they come early to secure a spot or pay to use the visitors lot, hence the high occupancy and early peak time for the free lot. Since these free lot users cannot be assured of a space if they leave and come back, they will prefer to finish all they need to do on campus before leaving. This explains the relatively longer parking durations. When people don't find spaces at the free lot and also cannot pay for a space at the visitors' lot or the on-street metered parking areas, the option then is to park at an area not designated for parking or park at permit areas they have not paid for.

Figure 4.8: Peak Parking Period and Excess Parking Supply for Free Lot



Source: MSU Parking Survey, 2012.

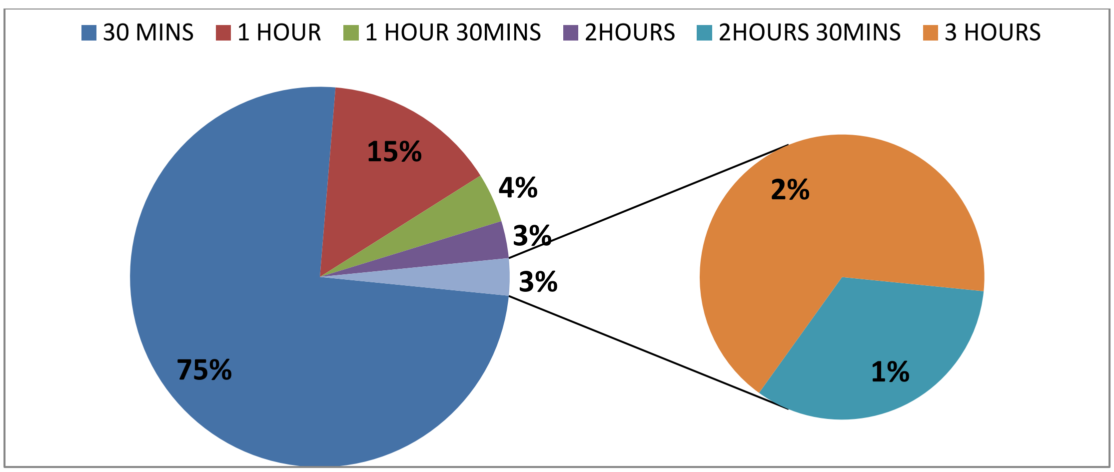
Photo 3: MSU's free lot (Lot 23 North & South) almost full at 10am to 12pm

Credit: Taken by Author during field survey on April 23, 2012

4.4 On-street Metered Parking Turnover and Peak Period

On-street parking serves an occupancy period of 15 minutes, yet none of the vehicles parked for less than 30 minutes at these spaces. As many as 75% of the spaces were occupied for 30 minutes while 15% were occupied for an hour (see Figure 4.9). It peaks at the 11-11:30 a.m. and 12:30-1 p.m. periods (see Figure 4.10). During these times, most parking facilities are also at their peak periods. The interesting thing about these parking spaces is that, they are ideal when there is excess demand at the surface parking spaces, else they only become an avenue to raise revenue from desperate parking users.[15] Most of these users may not have permits to the spaces which are at the core of campus; however their need to get close to their location at a fairly low price results in their use of these spaces.

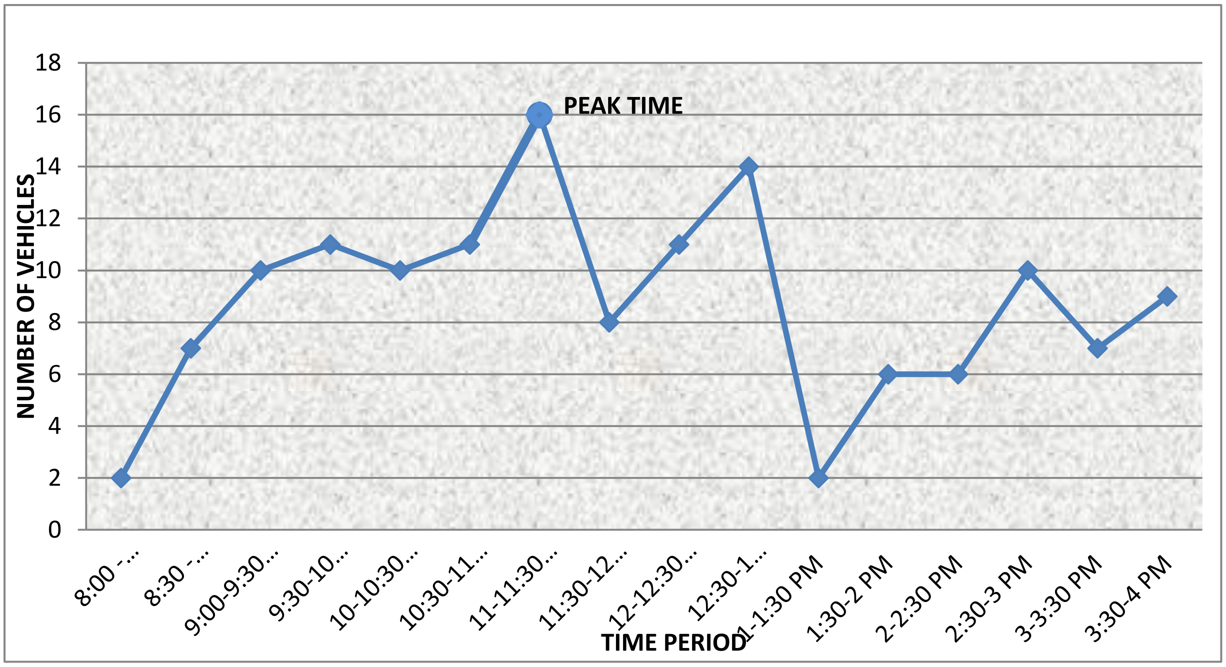
Figure 4.9: On-Street Metered Parking Turnover for South and Maywood Roads



Source: MSU Parking Survey, 2012.

[15]The case can be made regarding the need for these on-street parking lots for visitors who come for short visits, mostly to the offices in the area. Such need has already been catered for by the provision of the off-street visitors lot (lot 4). Therefore, the argument here at its core deals with parking "proximity", which translates into "convenience parking" for visitors. If a visitor chooses such on-street parking spaces for convenience reasons, then price paid should be more than that paid at the off-street visitors lot. Else, more people (visitors or not), with no parking permits will use the on-street parking facilities other than the surface ones. Aside the issue of congesting the road (since visitors will spend time cruising to find vacant on-street parking spaces), the other issue of revenue loss to the University also comes into play.

Figure 4.10: Peak Parking Period for South and Maywood Roads On-Street Metered Parking



Source: MSU Parking Survey, 2012.

4.5 Parking Prices/Fees

MSU's Parking Advisory Committee determines the prices for each of the parking permits. The major determinant of how much to charge per space rests on the ability to generate enough revenue to cover the cost of parking for the academic year under consideration. From the 2002/2003 to 2011/2012 academic years (see Figure 4.11), there has been an increase of 12.4%, 14.3%,15.5%, 13.3% and 16.1% changes in the prices of gold, orange, purple, light green and dark green permits respectively. However, the proposed increase in parking prices for 2012/2013 academic years for each of the parking permits, will mean that there will be a 16.1%, 29.2%, 29.9%, 31.8%, and 141% increase in prices for the gold, orange, purple, light green and dark green [16] permits respectively.

The idea that the percent increase in prices for the 2012/2013 academic year is much higher than even the percent increase for a ten year period (2002/2003 to 2011/2012) sounds preposterous especially to faculty/staff who argue that they have not received an increase in salary for the past few years. This is a manifestation of some of the controversies faced when parking pricing is faulty (not determined by market forces and based on average instead of marginal pricing) on campuses. Sustaining these parking fees in the near future can prove to be difficult. Hence the argument of restructuring the price system to allow market forces to determine prices and also making prices marginal instead of the average.

Further, the pricing history for parking spaces at MSU, shown in Figure 4.11, presents three main phases of pricing changes from the 2002/2003 to 2011/2012 academic years. The first phase starts from the 2002/2003 to 2005/2006 academic years, which had a base price of $210, 84, 116,150 and 62 for the gold, orange, purple, light green and dark green permits respectively. The second phase (2006/2007 to 2007/2008) recorded a percentage increase of 9.5%, 11.9%, 12.1%, 10.7% and 12.9% in the prices of gold, orange, purple, light green and dark green permits respectively, The third phase (2008/2009 to 2011/2012) recorded the lowest increase in parking prices. The percentage increases were

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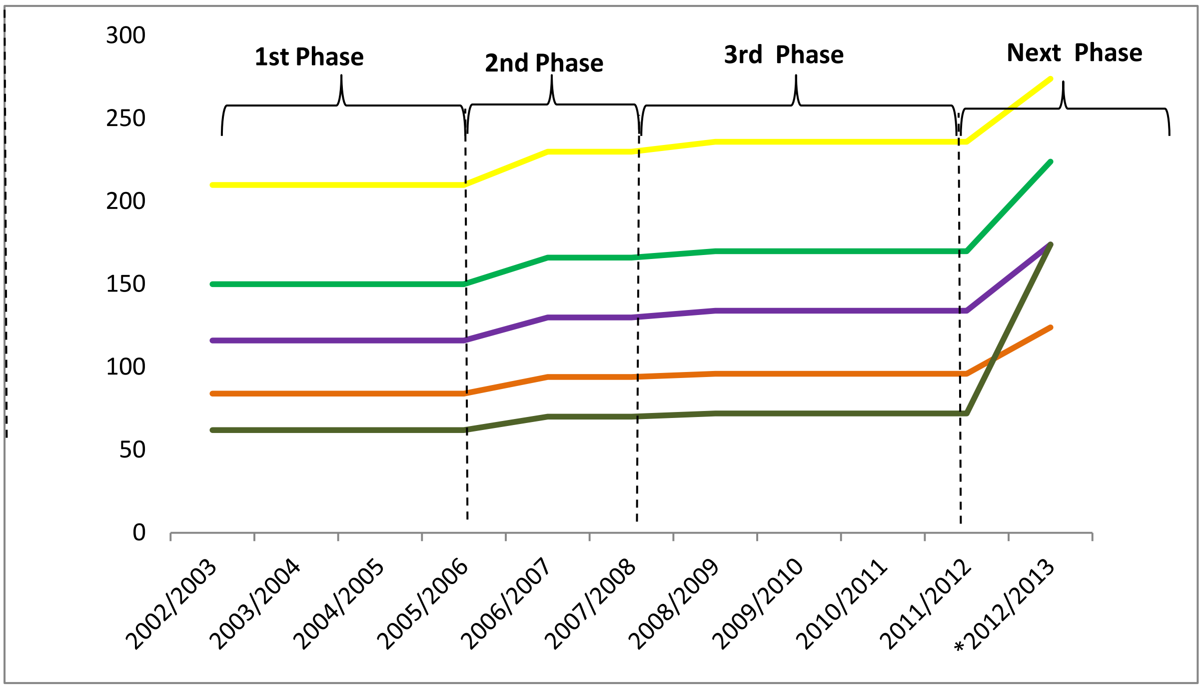
[16] In the case of the dark green permit, the increase is 2.4 times the price charged in 2011/2012 academic year. As earlier explained the high occupancy levels recorded during the survey at the dark green permit category is a possible reason for the price increase.

2.6%, 2.1%, 3.1%, 2.4%, and 2.9% respectively for the gold, orange, purple, light green, and dark green permits. The 2012/2013 prices shows another phase of pricing which is still yet to be determined in terms of how long it can be sustained.

Figure 4.11: Parking Price/Fee History of MSU



Source: MSU Parking Survey, 2012.

CHAPTER FIVE

THE COST AND BENEFIT OF PARKING ON MSU CAMPUS

5.1 Introduction

As price per parking permit increases on campus, parking authorities are somehow seen to be insensitive to the harsh economic realities currently being faced by all and sundry. Perhaps these users may in a way be justified for their outburst whenever parking prices increase since they are often not aware of the "cost" of parking. If users are made to understand that "parking will always generate enough to offset its costs, if users pay the full cost thereof," then they may understand the implications of their transportation behavior which informs the demand and supply of parking spaces. Perhaps then, such an implication will better enhance their understanding of the need to better adjust their demand so that minimum parking spaces may be supplied at the minimum price level to generate the maximum revenue needed to offset the minimum costs of parking.

The discussion of the demand for parking in MSU in this Chapter will focus on the peak use of parking spaces on campus. The trend and factors for parking demand will be discussed to understand the behavior of parking demand on campus. The Chapter will then proceed to discuss the cost and benefit of parking on campus by narrowing down on cost-benefit ratios and their implications on current campus parking measures. The Chapter concludes with the "green transportation fee" which is a policy designed to help make campus transit pay for itself. The argument here is that using parking revenue to pay for transit results in parking budget deficits. Two counter arguments are raised as to why the annual parking budget deficits cannot be associated with the fact that parking revenues are used to subsidize the bus routes on campus. By this, an extension can be made to the argument that, the "green transportation fee" which is a means of making transit pay for itself will not be sustainable in adjusting the annual parking deficits. If anything at all, making transit pay for itself raises a counter argument as to whether or not parking indeed pays for itself or better still, "do parking users pay for the full cost of using the parking spaces?" Possible measures in off-setting parking cost will then be briefly discussed with reference made to the system-based model for campus parking demand, supply, pricing, cost and benefits, as discussed thoroughly in the next Chapter.

5.2 Parking Demand

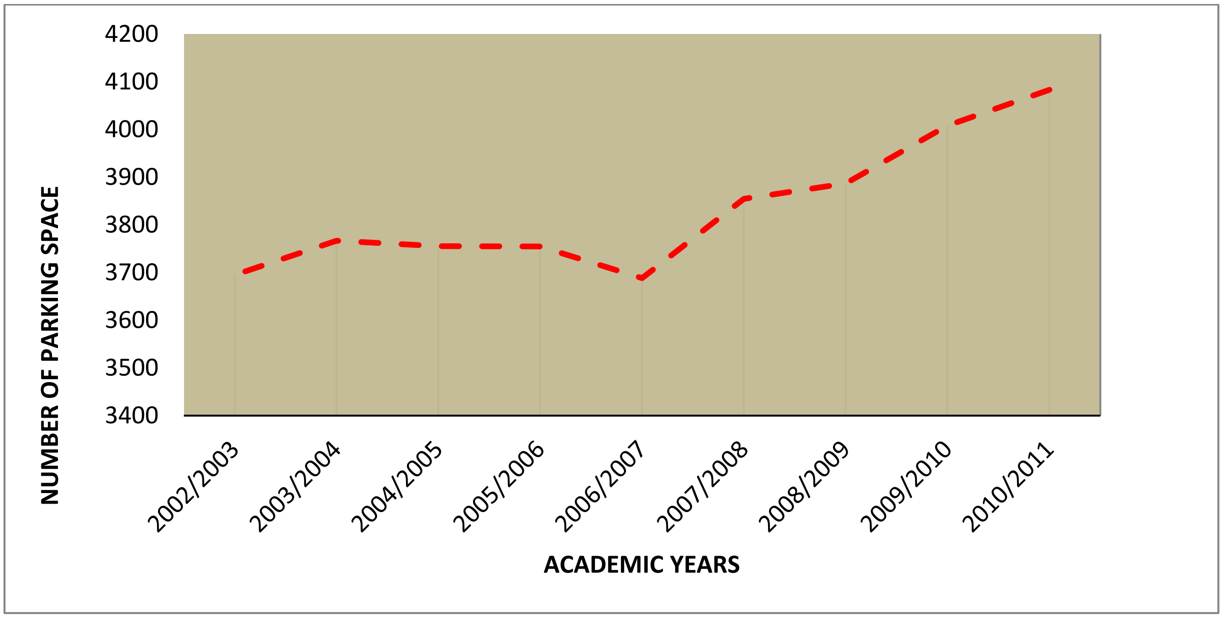
Parking demand, as already explained, looks at the maximum number of parking spaces occupied at the peak period. The dilemma in campus parking decision-making as considered in literature often arises when demand is conceptualized as the number of people who purchase parking permits. Often, this number may be twice the number of parking spaces available. The rationale for such a decision lies in the notion that "not all people will park at the same time within the day". Implicit in this rationale is therefore the understanding that there is a maximum number of people, often less than the number of people who purchase the parking permits, who park at the parking spaces available. Knowing that time of the day when the maximum number of people are parked (the peak hour), indicates the parking demand. When more than 85% of the spaces are occupied, then demand shortages may be an issue for parking policy decisions, and less than this implies surplus.

For the parking user groups in MSU (resident and non-resident students, and faculty/staff), each parking space is sold to at least two people for all the academic years under study. For instance, in the case of the total number of permit spaces available to non-resident students and faculty/staff, each parking space is sold to two or more people (see Table at Appendix 8 on the ratio of permits to parking supply). However, this in no way imply that there is more demand for parking spaces by any of these users, since as the previous Chapter explains, except for the "dark green permits", hardly do any of these permit spaces attain full occupancy even at their peak hours and at the 85% occupancy level. In other words, the fact that more people are purchasing permits cannot be used as an indicator of increasing demand.

Within the context of the discussion above, the demand for parking spaces at MSU, measured by the number of spaces occupied at peak periods, is shown (in Figure 5.1) to be increasing since the 2006/2007 academic year. The behavior of this demand trend is an amalgamation of the behavior of the demand trends for resident students, non-resident students and faculty/staff (respectively shown in Appendix 9, 10 and 11). Although each demand trend is showing some unique characteristics, synchronizing them presents a demand trend which was relatively constant, decreased and increased significantly from 2007/2008 to 2010/2011 academic year.

The demand trend for resident students also indicates decreases from 2003/2004 to 2006/2007 and then an increase from 2007/2008 to 2010/2011. That of non-resident students shows an increase until 2005/2006, decreases in 2006/2007 and 2008/2009, and increases from 2009/2010 to 2010/2011. The demand for faculty in absolute values can be seen to be relatively constant since its values ranges between 800 and 860 spaces. With the exception of 2008/2009 and 2010/2011 which saw decreases in demand, all the other years saw increases in demand.

Figure 5.1: The Overall Demand Trend for MSU (2002/03 to 2010/11 academic years)



Source: Author's Construct, 2012

5.2.1 Factors for Demand Increases and Decreases

Price per parking space, supply of parking spaces and the use of alternative means of transportation to and from campus could be seen to influence the demand trends. Most importantly, the trend of pricing, categorized in phases in the previous Chapter, to an extent explains the overall demand trend. Pricing potentially influences supply and also determines how many of parking users will switch from using their own vehicles to and from school and consider using buses, carpooling/sharing, bicycles, motorcycles or even walk. To therefore understand the demand trends, the phases of price increases were used to examine the behavior of demand, supply and parking substitutes.

A. First Increase in Price for the Study Period - 2nd Phase of Pricing

Price increase for the 2006/2007 to 2007/2008 academic year:

- *Demand*

a. The overall demand decreased in 2006/2007, and then increased again in 2007/2008.

b. Demand for resident and non-resident students also decreased and increased in 2007/2008.

c. Demand for faculty/staff still increased for these two years.

- *Supply*

The overall parking supply as well as supply for all user groups was constant.

- *Parking Substitutes*

a. The number of resident and non-resident students who used alternative means of transportation to and from campus, decreased in 2006/2007 and increased in 2007/2008.

b. The number of faculty/staff who also used alternative transportation means however increased for these two years.

B. Second Increase in Price for the Study Period - 3rd Phase of Pricing

Price increased for the 2008/2009 academic year:

- *Demand*

a. Overall parking demand increased but at a decreasing rate with demand for resident students also increasing but at an increasing rate.

b. Demand for non-resident students and faculty/staff however decreased.

- *Supply*

a. Supply remained relatively constant for 2008/2009 and 2009/2010 for all users.

b. The overall supply and supply for resident students in 2010/2011 increased significantly but decreased for non-resident students and faculty/staff.

- *Parking Substitutes*

a. Substitutes for resident students increased throughout these years.

b. Substitutes for non-resident students decreased in 2008/2009, increased in 2009/2010 and decreased again in 2010/2011.

c. Substitutes for faculty/staff increased in 2008/2009 and decreased for the remaining two years.

5.2.2 Demand Elasticity as a Probable Cause for the Unique Behavior of Demand Factors

In all the above phases of price increases, demand, supply and parking substitutes behaved in unique patterns, making it difficult for generalization. An underlying influence for the unique behavior of these factors should consider the elasticity of demand. In the absence of suitable parking alternatives, as price changes, demand responds in the first instance, but the response is not long lived. Demand most of the time decreased or increased at a decreasing rate when price increase was introduced, but the decrease could not be sustained.

Explaining the above phenomenon further, two interrelated issues play a key role and these are: how fast campus parking users adjust to price changes and the quality or even sometimes the quantity of transportation alternatives available on campus. Parking users on campus adjust faster to price increases because there are no considerable transportation alternatives, especially for those users who live outside of Mankato. Even those who live off-campus but within Mankato have issues with the limited service coverage of Mankato's transit service in terms of distance and hours of operation. In the 2011 Mankato Transit Redesign Study, in all instances, more than 50% of campus respondents indicated that their ridership of buses will increase if additional routes were added, increases were made to the hours of operation for both weekdays and weekends, and evening and morning hours of operation were extended.

In summary therefore; "an initial change in price with initial supply constant, ***causes demand to be elastic in the short-run, but become inelastic in the long-run, if supply is also constant in the long-run".*** For instance, when price changed in both phases, with the exception of demand for faculty/staff in the second phase of pricing all other demand responded by either decreasing or increasing at a decreased rate. However, such decreases or increases were not sustained since demand returned to its increasing behavior.

Again, except in 2010/2011, supply was also seen to be relatively constant for all these user groups throughout the study period. An initial change in supply with price constant was also seen to cause ***demand to be elastic in the short-run but inelastic in the long-run, if price was also constant in the long-run,*** since parking spaces were mostly constant for a long time. This is illustrated from the information above that, as supply changed in 2010/2011, overall demand and demand for resident students increased though at an increasing and decreasing rates respectively. Demand for non-resident students and faculty/staff decreased. So, when supply increased for resident students, their demand increased, but since supply decreased for non-resident students and faculty/staff, their demand decreased.

Also worthy to note is the understanding that ***parking supply is inelastic to price changes in the short-run*** since it takes longer time span to either construct and/or demolishes these spaces. They however become ***elastic to price changes in the long-run.*** Thus, for both the second and third phases of parking pricing, it was seen that supply could not change much even though prices increased. It was until 2010/2011that supply could be adjusted for all user groups.

5.3 Causation and Correlation of Parking Demand: Relationship between Demand and its Factors

Having an understanding of the trends in demand and the role played by the above specified causal factors of price, supply and substitutes, the approximate effect of one on the other was investigated using a multivariate regression analysis. This was done for each of the parking users by comparing their beta values as a stepwise regression was being conducted. The results of comparing these beta values measured the degree of influence that these factors had on each other. The results therefore helped in understanding the causal elements of parking demand on campus. Similarly, some factor(s) may just have had some correlation with demand but were not necessary the cause(s) of parking demand.

5.3.1 Demand for Resident Students

Demand was regressed on supply, prices/fees and number of people who use alternative transportation means to and from campus. The results, summarized in Appendix 11 concluded the following:

- ❖ Regressing Parking Demand on Parking Supply and Parking Prices/Fees shows that;
  - a. fees resulted in a decrease of 27% in the original value of supply.
  - b. supply also resulted in a decrease of 24% in fees.
- ❖ Regressing Parking Demand on Parking Supply, Parking Prices/Fees, and Parking Substitutes indicates that;
  - a. Parking substitutes created a decrease of a little more than twice the sizes of price and supply
  - b. Only 0.5% increase in substitutes was as a result of parking supply and fees.

In summary, substitution decreases supply and prices. As resident students use alternative transportation means on campus, their demand for parking spaces will decrease. With such decrease in demand, the worth (prices) of parking decreases, limiting the quantity of spaces allocated for resident students' parking.

5.3.2 Non Resident Students

For the non-resident students (see summary in Appendix 12), the results indicated the following:

- Regressing Parking Demand on Parking Supply and Parking Fees shows that;

    a. fees affected an increase in supply by more than **twice** its original value.

    b. supply also resulted in an increase of more than **six times** the value of price.

- Regressing Parking Demand on Parking Supply, Parking Fees, and Parking Substitutes;

    a. parking substitutes influenced a decrease of 43% in supply and an increase of 40% in fees.

    b. parking supply and fees resulted in a decrease of 5% in parking substitutes.

Unlike the case of resident students, substitutes for non-resident students decreases supply and prices but the percent of decrease is not as high as that recorded for resident students. Non-resident students mostly rely on their private vehicles because they have limited alternative means of transportation to campus. Hence, even as they try to use these alternatives, their demand for spaces will not be such as to warrant a more than half decrease in supply and prices available.

5.3.3 Faculty/Staff

Finally, for the faculty/staff (see summary in Appendix 13), the analysis presented the following conclusion;

- Regressing Parking Demand on Parking Supply and Parking Fees shows that;

    a. fees impacted supply by reducing its value by **85%** of its value.

    b. supply also resulted in a **7%** decrease in price.

- Regressing Parking Demand on Parking Supply, Parking Fees, and Parking Substitutes shows that;

    a. parking substitutes, influenced decreases of **124% in supply** and **94% in fees**.

    b. parking supply and fees only had 6% decrease in parking substitutes.

Substitutes in the case of faculty/staff seem to have effects on supply and pricing similar to those of resident students.

5.3.4 Summary of Causation and Correlation of Parking Demand Factors

The beta comparisons show some correlations between parking demand and its factors. Irrespective of such correlations, causation cannot be imputed to all of these factors. When supply increased or decreased, demand, price and substitutes did not necessarily behave likewise. Price and substitutes on the other hand had an interesting influence on demand. In these factors we can see traces of causation for parking demand on campus.

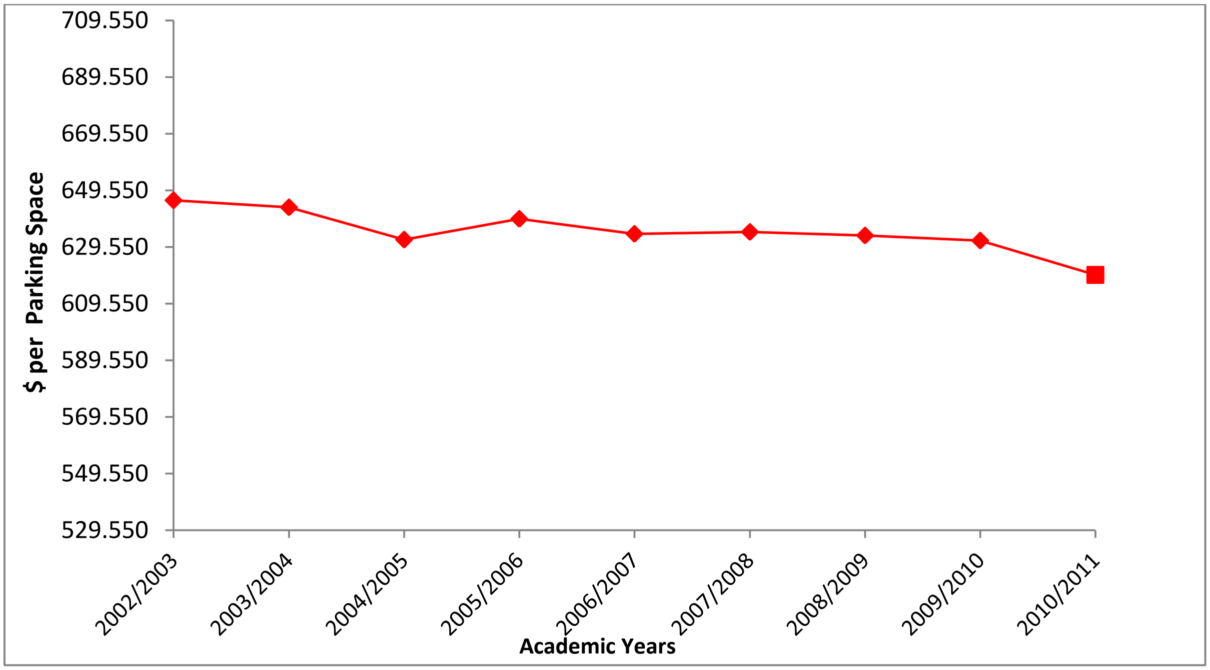
The interesting thing about these two factors is how they are intrinsically intertwined in terms of their effect on demand. Prices as earlier explained may cause demand to decrease base on the demand elasticity. Such demand elasticity is equally influenced by the quality of alternative transportation means on campus. Thus, as these alternatives improve, campus parking users may switch to these alternatives. The issue is fuelled further if improvement in such alternatives (especially the Mankato bus transit) is met with a corresponding increase in parking prices.

5.4 The Cost of Parking at MSU

Cost for parking spaces considered the OM, construction and land costs for parking spaces (see Appendix 14). Since the annualized capital costs (land and construction costs) per space were constant for all the years, the annual cost per space was essentially determined by the annual OM cost. The average cost per parking space for this study period was about $629. In using a four-year simple moving average (see Figure 5.2), annual cost for parking reached an almost even average of about $634 from 2006/2007 to 2008/2009, and reached its lowest average of $619 in 2010/2011. The moving average suggests the trend that cost per parking space is reducing throughout this period. The question to be answered is whether, despite the reduction in cost, annual parking price per space meets the annual cost per parking space. The answer to this may vary depending on which of the three costs (OM, land, and construction) are taken into account in parking price decisions.

It is also worthy to note that since parking permits sold mostly exceeds the number of parking spaces available - implying that each space is sold to more than a user- revenue generated annually per space is often twice its price. Therefore in instances where prices are low enough to guarantee more permit purchases per each space, revenue generated per space may meet its annual OM cost. Similarly, spaces which have high prices (like the gold permits) and equally higher purchases make it possible that the annual revenue per space meets the annual OM cost. In all these instances however, only the OM cost are met and not the total cost (which is the sum of the OM and capital cost).

Figure 5.2: Four-year Moving Average of Parking Cost per Space in MSU



Source: Author's Construct, 2012

Comparing the prices/fees for each of the parking permits with the costs (OM, land, and construction), even for the highest-priced gold permit parking spaces, except for 2002/2003 the price was less than even the OM cost alone (see Figures in Appendix 15, 16, 17, 18, and 19). For the study period, considering only the annual OM cost for parking spaces, the average price paid by parking users for gold, light green, purple, orange, and dark green permits respectively were 14%, 38%, 52%, 65% and 74% less of the actual annual OM cost (without even the annualized capital cost) per parking space, not even adding the annualized capital cost). Hence, the answer to the above question of which costs is taken into account in campus parking pricing decisions, can comfortably be answered with the word "None".

As Shoup (2008) points out, the argument here is not to price campus parking spaces like any other economic commodity. Instead, what the above finding of pricing discrepancy in MSU only suggests is that pricing of parking spaces is often less than their economic value, not even considering the environmental cost. If parking pricing does not reflect the "break even" pricing level, then how much is really being subsidized for providing campus parking facilities is of interest here.

As pointed out by Martens and van Luipen (2009), parking pricing being less than the economic value for parking spaces could mean either that the benefit is being underpriced or supply exceeds demand. In the case of MSU, not ruling the former out completely, the latter seem to be the most obvious scenario. Establishing the latter scenario led to the estimation of what is referred to as the "cost excesses".

5.4.1 Cost of Demand vs. Cost of Supply: Cost Excesses

If parking spaces available each year have associated costs, then to ensure that the University does not incur too much cost it may be a better approach to provide parking spaces equal to what is demanded. Cost excesses will therefore be an issue if there are more parking spaces than what is demanded. In such a case, choices will have to be made about how much of the excess cost is passed on to the parking users and how much the University assumes. When the University subsidizes the cost as a result of not passing on the excess cost to the parking users, then financing these excesses will lead to an often unattended question of who actually pays for parking on campus--is it only the parking user, or both the parking and non-parking users?

From 2002 to 2011, two significant findings can be identified with respect to the cost of parking supply and demand. The first is the annual parking cost deficits as the University tries to supply parking spaces in meeting the demand (see Appendix 20). The lowest deficit of $56,000 was recorded in 2011. As explained earlier, these deficits are not as a result of cost exceeding revenue. Instead, they are as a result of demand exceeding supply. The result is that annually more spaces are supplied than are needed, causing the University to spend more on annual OM cost.

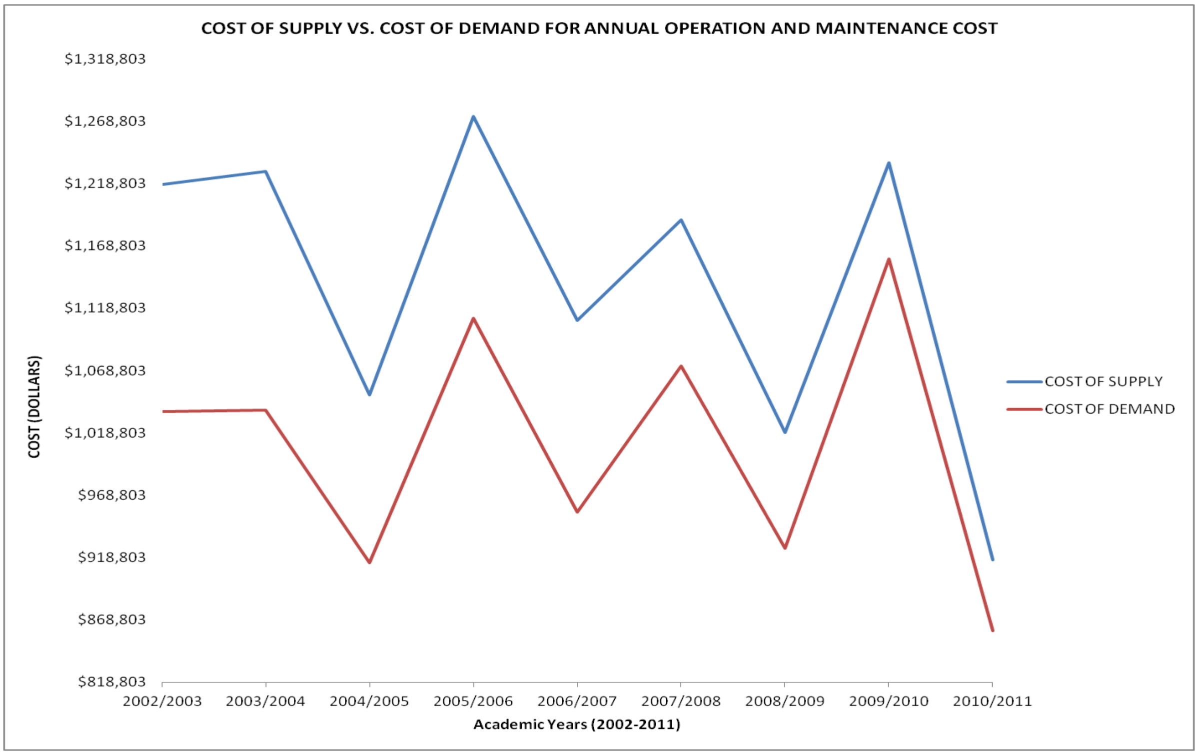
The second finding relates to the fact that, although there have been annual cost deficits, as the years go by, the deficit gap have been seen to be closing for both the annual OM cost and capital cost (see Figure 5.3 for the case of annual OM cost). The implication here is that the supply of parking spaces is now seen to be gradually meeting demand. This can have multiple causes including demand having been reduced while supply increased, supply increasing at a faster rate than the increase in demand, or the demand decreasing at a faster rate than the decrease in supply.

Since parking on campus is seen to annually generate enough revenue to cover its annual OM cost, then this cost excesses issue does seem not to make much sense or better still, to be of no importance. On the contrary, these excesses in their simplest economic terms mean that if, annual supply is made to meet demand:

a. revenue will be maximized since cost will be minimized through the elimination of subsidies; and

b. with revenue maximized, prices may be looked at again for possible reduction since the University can now eliminate excess OM cost on excess supply.

Figure 5.3: The Closing Gap Between Annual OM Cost of Parking Supply and Demand



Source: Author's Construct, 2012

5.5 Benefit-Cost Ratio of Parking: Cost Subsidization Due to Faulty Pricing

Available records shows that for the 2004, 2006, 2008, 2010 and 2011 fiscal years, the annual parking OM cost exceeded revenues. In its defense, the use of parking revenue to subsidize the cost of Mankato bus transit on campus is a major, if not the only, reason for the annual parking budget shortfalls; hence the introduction of the "Green Transportation Fee" in 2012 to make campus transit system pay for its cost.

As plausible as the "Green Transportation Fee" may be, it still does not answer the question of whether parking users on campus actually pay for the full cost of their spaces. Two arguments may be put forward to underscore the question. The first relates to the myopic view of how parking cost on campus have been presented. As argued right at the inception of this study, parking cost goes beyond the annual OM cost. As shown in Table 5.1, the annual benefit-cost ratio of parking is not more than 0.5 for all the years under study, meaning that the cost is always twice the benefit MSU derives from parking. However, since annual parking cost is always calculated in terms of the OM cost, without considering the cost of land and the opportunity of cost of converting these campus lands into parking spaces, parking cost is often times underestimated.

Table 5.1: Annual Cost-Benefit Ratio of Parking on Campus

Academic Years	Annual Cost of Parking Spaces ($)	Annual Revenue of Parking Spaces ($)	Benefit-Cost Ratio
2010/2011	2508206	1203590	0.5
2009/2010	2799632	1208568	0.4
2008/2009	2582729	1256103	0.5
2007/2008	2753476	1278736	0.5
2006/2007	2674403	1302731	0.5
2005/2006	2846119	1214815	0.4
2004/2005	2623720	1260758	0.5
2003/2004	2859806	1213015	0.4
2002/2003	2807678	1155160	0.4

Source: Author's Construct, 2012

Further, since parking generates enough revenue to cover its annual OM cost, propositions for converting vacant lands to construct parking spaces may seem desirable. However, not only has it been seen through earlier analysis that the cost have always exceeded the benefits, it has also been seen that parking supply actually exceeds demand annually. Faulty pricing has created spots of vacant spaces at some parking lots while others have exceeded their limits, making it seem as though there are parking supply deficits on campus.

The second argument rests on the tenets of complimentarity that parking provides to the means of transportation on campus. In fact, the introduction of the "Green Transportation Fee" is tenable if parking is now seen to be mutually exclusive to transit provision and all the other components of the entire Transportation framework of MSU. The value of parking permits is enhanced by the provision of free bus passes to the orange, dark green and purple permit holders. Hence, associating the annual parking budget shortfalls with subsidy for buses on campus ignores the value that the buses add to the parking permits. As far as the dark green, orange, and purple permits are from campus, people will still buy them even as prices increase since they have buses available to convey them to campus.

As this study posits, the University needs to examine two interrelated measures if it wishes to balance the cost and benefits of parking. The first should look at cutting down on parking supply excesses by matching demand to supply. The second measure deals with price controls, since the price per parking space does not even meet the annual OM cost of parking on campus. Both measures have a way of achieving an "equilibrium parking price" for each permit so that not only will demand meet supply, but benefits will also meet or even exceed costs. The next Chapter discusses these interrelated measures to produce an equilibrium price through the design of a system-based parking model.

CHAPTER SIX
ACHIEVING OPTIMUM PARKING EFFICIENCY - A SYSTEMS APPROACH TO PARKING POLICY ANALYSIS

6.1 Introduction

At the core of this study is the determination of what should be an "optimum parking price" to achieve "optimal parking balance" on campus. The discussions so far have been a retrospective analysis of MSU's parking policies in terms of parking demand, supply, pricing, cost and benefit trends. The crux of the discussion here is in developing an economic model for making parking decisions focused on achieving the optimum parking price.

Achieving the "optimum parking price" may equally be as complicated as the model used in achieving such price. This happens if the model's parameters exceed what can realistically be modeled. In effect, a model developed to answer all questions may end up answering none. The systems dynamics method was used to form a model to answer the question of how much we should charge for parking on campus. The answer to this question will aid in finding the maximum price which also ensures that:

a. parking demand equals/or is most close to supply, to avoid surpluses and shortages and ultimately contribute to the efficient use of campus lands; and

b. at the minimum supply, there will be the guarantee for enough purchases to make parking benefits at par with at least, the annual OM cost of parking.

The use of the system dynamics method is motivated by the understanding that parking is a microcosm among other microcosms that are intertwined in forming the broad campus transportation framework. A model that tries to mimic to an acceptable level, the complexities of such interrelationships must link these parts to form a holistic unit (system), to help predict the behavior of each part in the context of the whole. The mechanics of system dynamics help in making such connections in the analysis and prediction of parking situations.

6.2 The Parking Model

Using Vensim PLE software, the model was categorized into two distinct parts. The first part (see Figure 6.1) dealt with the demand, supply and pricing for each of the parking permits considered for this study (gold, orange, purple, light and dark green). The second (see Figure 6.2) used the information from the first (demand, supply and price levels) to determine the cost and benefit (revenue). A five year estimate was used as the time trend for the model.

6.2.1 Modus Operandi of the Model

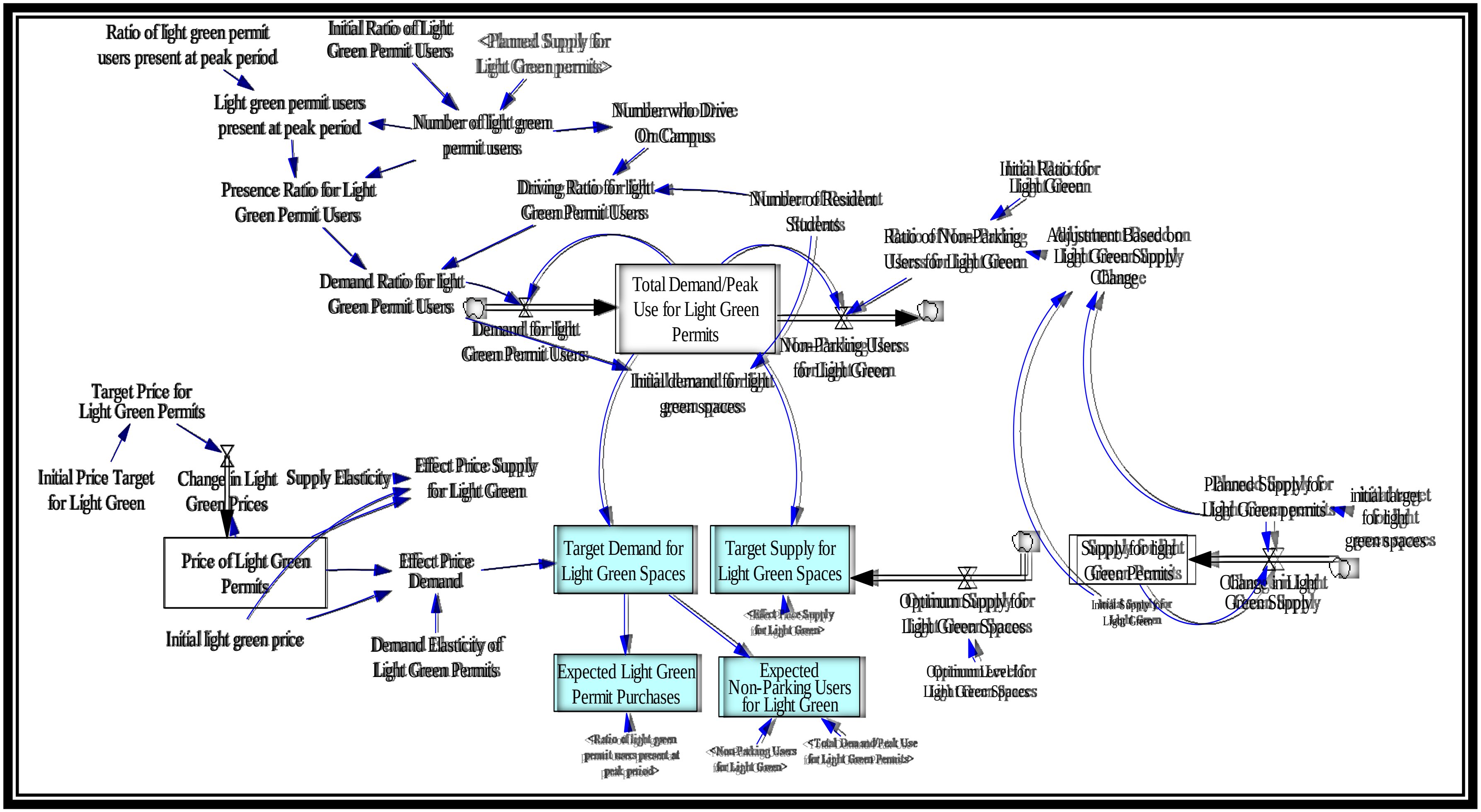
The model like any system operates on some sets of "inputs" and "outputs" which can essentially be referred to as the model "variables". These inputs were either numerical figures, equations or a combination of these two. Depending on the information contained in the variable, the variable can either be termed as "level, "rate", "auxiliary", or "constant".

- ***Levels:*** They work by integration over time based on their previous value as well as the previous values of other variables.

- ***Rates***: They are thought of as an auxiliary used in changing a Level.
- ***Auxiliary:*** They have no memory, and their current values are independent of the values of variables at previous times.
- ***Constants:*** These values do not change with time.

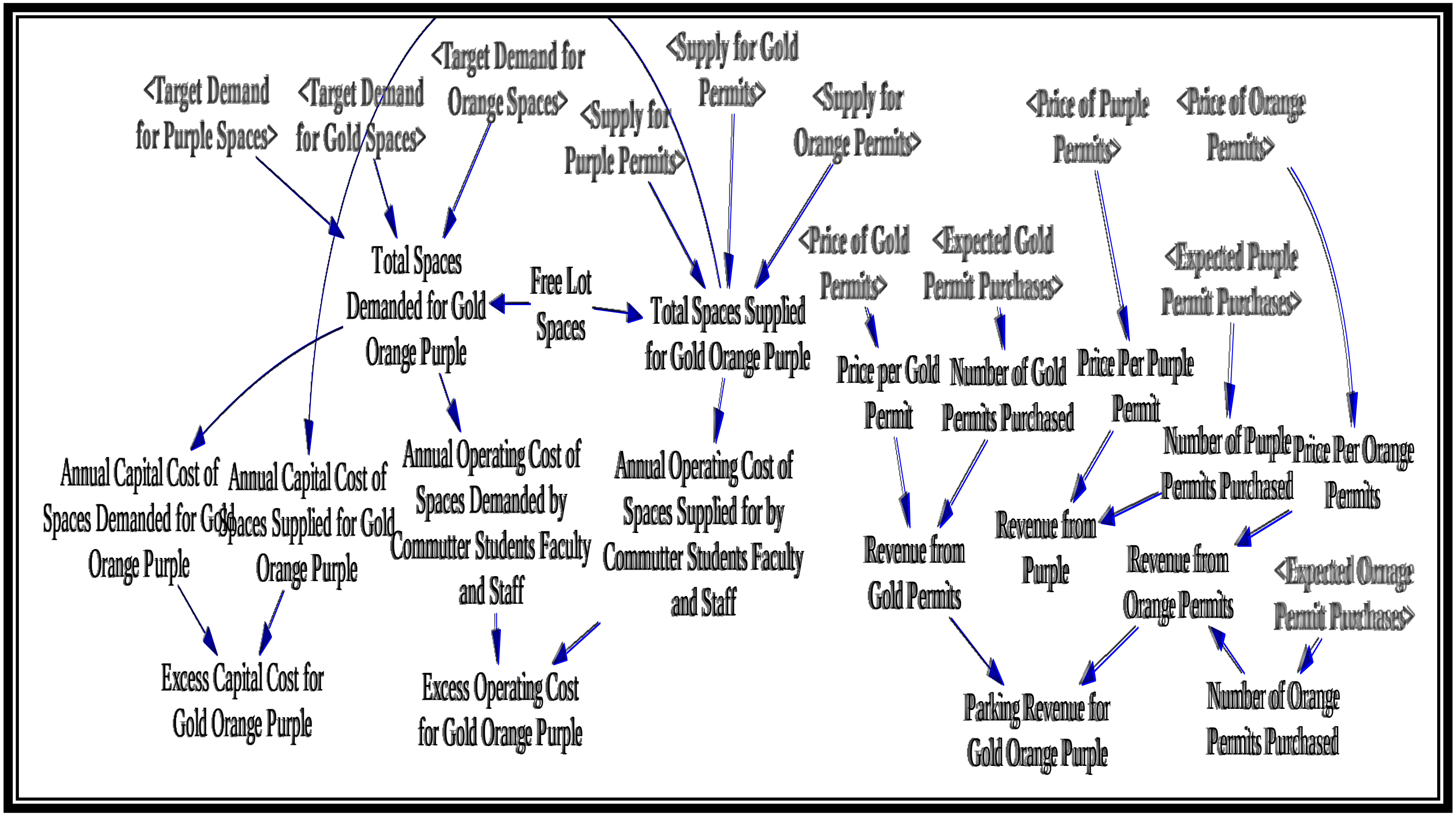
The only levels in the model are "Total/Peak Use Demand", "Price", "Non-Parking Users" and "Supply". The "change in supply", "change in price", "demand", "non-parking user" and "optimum supply" are the only rates in the model. The rest are either auxiliaries or constants. During simulations, the constants could be changed to identify their impacts on the auxiliaries and levels.

Figure 6.1: An Example of the Vensim-based Parking Demand, Supply and Pricing Model



Source: Author's Construct, 2012

Figure 6.2: An Example of the Vensim-based Model for Parking Cost and Benefits (Revenue)



Source: Author's Construct, 2012

6.2.2 The General Description of the Model

Parking demand, defined in terms of the maximum vehicles parked at the peak period, was the primary variable determined. The determination of this was based on two constants which were; the "ratio of users", and the "ratio of the users present at peak period" for a particular parking permit group. These ratios could be determined arbitrarily. However, to make sure that they reflected prevailing situation, the 2011 data was used in their estimation.

Therefore, since each parking permit group had a number of purchases made, the ratio of users was determined by finding the proportion of permits purchased to the number of parking spaces/supply available to that permit. Hence, it was assumed that the University will not sell more than a given percentage of the spaces available to that permit group annually. Also, based on the parking occupancy survey, the number of permit group users present at peak period was also expressed as proportion of the number of permit purchases for that permit group.

For instance, if the number of light green purchases for 2011 was 10, the number of light green spaces was 8, and the number of light green permit users present at peak period was 5, then the "ratio of light green permit users” will be 1.25. To therefore determine the “number of light green permit users,” we multiply this ratio by the number of light green spaces (8), to get 10 light green permit users. Also, the number present at peak period (5) was divided by the number of users (8) to get the “ratio of users present” at peak period. As mentioned earlier, any time the total supply changed (increased or decreased), whether or not the ratios changed, the number of permit users and permit users at peak period will also change. The opposite holds true if the ratios also changed.

So,

$NP = Rp * TS$ ....Equation 7

$NP_p = RP_p * NP$ ....Equation 8

Where;

NP = Number of permit users

NP_p = Number of permit users present at peak period

Rp = Ratio of permit users

RP_p = Ratio of permit users present at peak period

TS = Total permit spaces/supply

The information was then used in determining the “presence” and “driving” ratios for the users of that permit group. The presence ratio is the number of users present a peak period while the driving ratio is the ratio of number of light green permit users to the total number of resident students since residents students are the only authorized user group permitted to purchase the light green permit. The product of these two auxiliary variables (presence ratio and driving ratio) was the “demand ratio.” This demand ratio when multiplied by the Total Demand/Peak use of the previous year, gave the additions to the current year. Since Total Demand/Peak Use operates as a "level" variable, its current value is an integration of the previous year's demand and what is currently being added. This is the first half of finding the Total Demand/Peak Use for a permit group.

So;

$Pr = NP_p / NP$ ....Equation 9

$dR = NP / TPU$ ....Equation *10*

$DR = Pr * dR$ ....Equation 11

$D = DR * TDp$ ....Equation 12

where;

Pr = Presence ratio

dR = Driving ratio

DR = Demand Ratio

D = Demand or the Demand Additions annually.

TU = Total Number of permitted users (This can be the total number of resident students or the total number of non-resident/commuter students plus faculty/staff).

TDp = Total Demand/Peak Use for the previous year

The second half of this calculation deals with the number of demand users who will no longer be using the permits. The dynamics here is simple but can be quite complex. For resident students, this number changes each year. What the model is saying is simply that the current year's demand may either be the same, greater or lesser than the previous year's demand. So, the "non-users" category means that a given ratio of the previous year's demand figure will no longer be using the permit. Therefore, total demand for any given year (let's say 2012) will be the demand for 2011, plus the demand additions for 2012, minus the "non-parking users" for 2012. This is essentially the same as projecting population change - the previous year's population plus the current year's births minus the deaths.

So,

NN = Rn * TDp ....Equation 13

where;

NN = Non-parking users Or Demand Subtractions annually

Rn = Ratio of non-parking users

Therefore

DC = $\int_{a}^{b} TDp + (D - NN)$ ....Equation 14

where;

DC = Current Demand

The price and supply elements of the model are two different levels. Both price and supply levels are assigned initial values. However, these values change based on their "rate" variables. These rate variables were influenced by the target sets. So when price target changes, the level variable of price also changes. The same occurs with supply, although the name of the target variable is changed to "Planned Supply". It is worth noting the demand and supply elasticities as well as their corresponding "effects". Two auxiliary variables, referred to as the "Effect Price Demand" and "Effect Price Supply," were calculated based on the equation for a standard constant elasticity demand/supply curve. These "effects" affected the target demand and the target supply depending on the change in price. So the higher the increase in price and the demand or supple elasticity, the higher the effect on target demand (in terms of "effect price demand") and on target supply (for "effect price supply").

So;

- ❖ Effect Price Demand

  =EXP(-Demand Elasticity*LN(Price/Reference Price)) ....Equation 15

- ❖ Effect Price Supply

  =EXP(-Supply Elasticity*LN(Price/Reference Price)) ....Equation 16

Note:

- ✓ EXP in both equations 9 and 10 returns "e" (2.718) to the power of "x" which are price elasticity and supply elasticity in both equations respectively.
- ✓ LN in both equations is the natural log of "x". where "x" in both equations is (Price/Reference Price).

The target demand and supply, which are influenced by the "effect price demand" and "effect price supply," only tries to help establish what should be the equilibrium price which will equate demand to supply. Supply in this instance is adjusted based on the 85% occupancy rule which states that supply should not exceed 85% of the total supply else there is a parking shortage. However, this figure was manipulated throughout the simulation exercises to identify possible impact on parking costs and benefits. The auxiliary variables of "Expected number of permit purchases" and "Expected non-parking users" only tries to identify what these variables looks like after price changes.

So,

tD   = DC * EPD ....Equation 17

$tS = (DC * EPS) * OPS$ ....Equation 18

$ENPp = tD$ ....Equation 19

$ENN = NN + (DC - tD)$ ....Equation 20

Where

tD = Target Demand

EPD = Effect Price Demand

tS = Target Supply

EPS = Effect Price Supply

OPS = Optimum Supply

ENPp = Expected Number of Permit Purchases

ENN = Expected Non-parking Users

Based on the above information, the cost and revenue part relied primarily on the target demand and supply as well as the prices to determine whether the existing price is "right" (optimum parking price).

6.3 Simulating the Parking Model

The purpose of simulating the model was to examine the hypothesis that; "If parking supply meets demand, cost will exceed the benefits." By simulating the model over a five year period, an understanding of the complex future impacts of current parking policies was elucidated simply in both analytic and graphic terms. Hence, a quick glance at the simulation results answers quick questions about how many parking spaces will be demanded annually at the current price and supply levels, how much will it cost (annual capital and operating costs), and will it generate enough revenue to offset the costs.

Although the model provides results for both capital and operating costs, in validating the hypothesis cost was discussed in terms of the total cost (the sum of capital and operating cost). The annual OM cost was used in the discussions of optimum parking price per parking space on campus. Attention would have been paid to the capital cost component if the decision to be made concerned new parking spaces to be constructed or those that have been existence for less than three years. In any case, the simulation results easily provide a graphical presentation of the cost impact if both the capital and operating costs are discussed.

6.3.1 The First Simulation

❖ *Parameters Used for the Simulation*

The Parking authority at MSU introduced a new parking policy which sought to adjust the current level of parking supply and prices (see Table 6.1) available to the resident students as well as those of non-resident students and faculty/staff. Using supply and prices as the model's inputs, the objective was to validate the study's hypothesis. This, by extension, was to project parking demand, cost and revenue. This answer will therefore aid in determining whether or not the new prices could qualify as what the study refers to as the optimum parking price, a price that should achieve the "optimal parking balance".

Table 6.1: University's Predictions based on the Introduced Parking Policy (2012)

Permit Type	New Supply	New Price ($)	Predictions	
			Permit Sales Ceiling	Estimated Permit Revenue ($)
Gold	913	274	1004	275, 275
Purple	954	174	1288	224,095
Orange	735	124	992	123,039
Light Green	605	224	635	142.240
Dark Green	660	174	700	121,800

Source: Parking and Facilities Management Office, MSU; February 2, 2012.

6.3.2 The Results from the First Simulation

A. Demand and Supply

For price increases across all permits, demand is expected to decrease in the first year (meaning in 2012) of introducing the new prices (see Figure 6.1). However, as identified from the previous demand trends, parking users quickly adjust to price changes as the years go by. A major reason for this behavior is the unattractiveness of the other alternative means of transportation (in particular, the Greater Mankato bus service from campus).

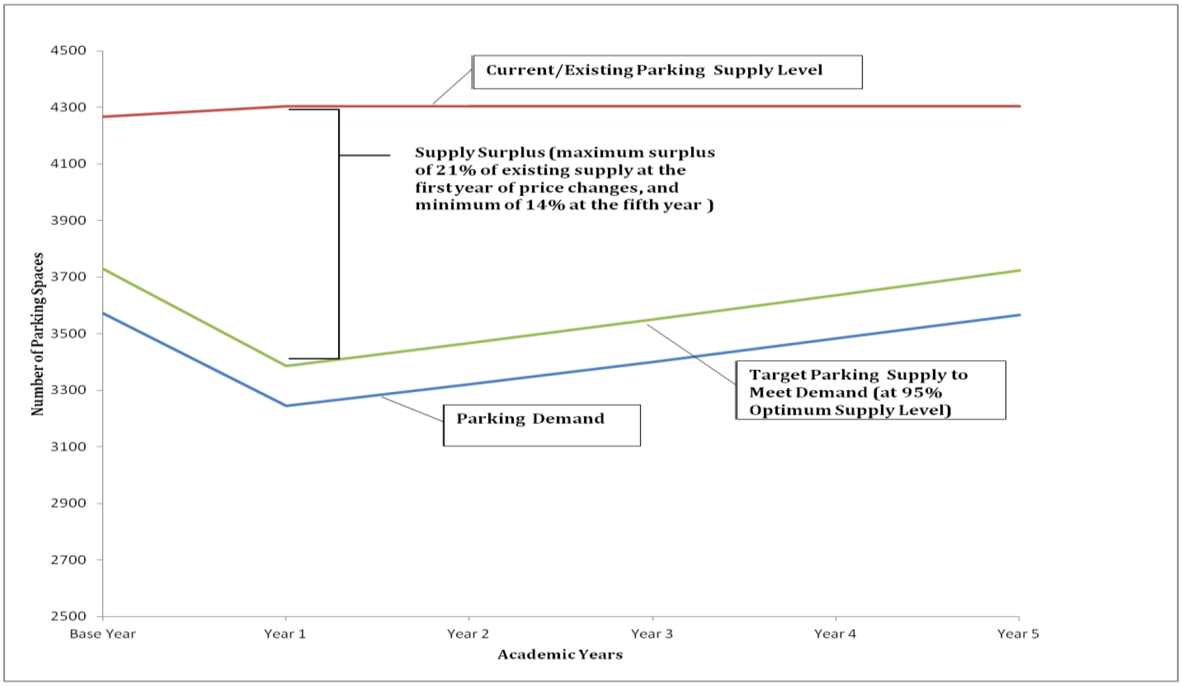
In a 2011 Greater Mankato Transit Redesign Study by the Urban and Regional Studies Institute (URSI, 2011), it was presented that ridership of the transit service by campus members is constrained by route and service limitations (days and hours of services provided). It has also been demonstrated that transit ridership, particularly among discretionary riders (those who can drive), responds to service improvements more than fare reductions (Evans, 2004; and Litman, 2012a). The model therefore captures decreases in demand and attributes that to price changes - meaning that parking usage decreases or increases as a result of price changes, not because of competing transportation modalities on campus.

This notwithstanding, the recent introduction of the "Green Transportation Fee" (GTF), which provides "free"[17] bus ridership to all students and some routes extensions may have an impact (probably a decrease) on parking demand. The impact of GTF on parking demand will also depend on the magnitude of bus service improvements. Campus

[17] The bus ridership is not entirely free since there is a 75¢ per credit hour fee paid by all enrolled students.

members will therefore need more bus routes and extended days and hours of operation if they are to get out of their vehicles and use the buses to, from and on the campus.

Figure 6.3: Annual Parking Demand and Supply from Simulating the First Simulation



Source: Author's Construct, 2012

B. Annual Parking OM Cost and Revenue

With the exception of the light green permit, the model projects much higher permit purchases and revenue, unlike the University's prediction (see Tables 6.1 for the University's prediction and 6.2 for the model's predictions). The model’s five year prediction shows gradual but perceptible increases in parking revenue. Also Figure 6.2 displays the various costs incurred should the University decide to provide a fixed supply or adjust supply annually to match projected demand. The latter requires more administrative effort to better predict demand for the forthcoming year and also monitor for adjustments during the year.

Increasing administrative effort suggests the proposition that future parking policies should consider metered parking with sensors (Shoup, 2008; and Nelson and Schrieber, 2012[18]); this permits one to measure demand as well as to regulate prices at parking locations based on current demand. This would distribute parking demand on campus, allow users to park at where they want and pay for the only the times they use the spaces, and eliminate the need to purchase a year-round permit.

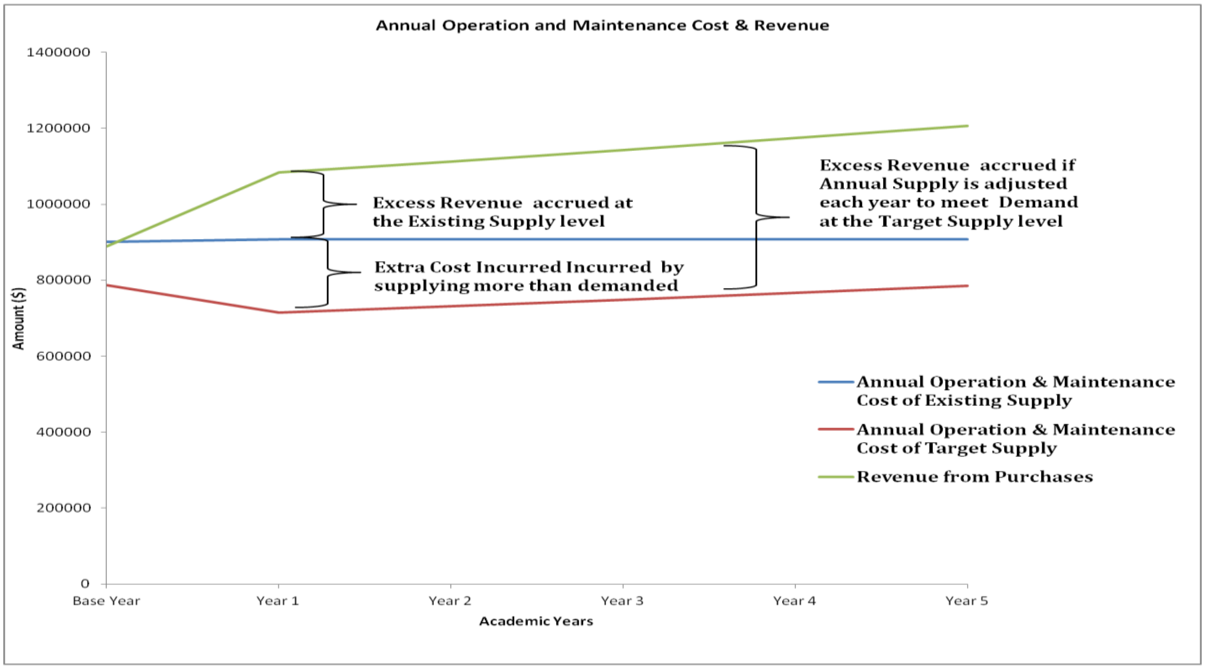
Table 6.2: Simulating the Model to Predict Parking Permit Purchases and Revenue

Permit Type	New Supply	New Price ($)	Predictions	
			Permit Sales Ceiling	Estimated Permit Revenue ($)
Gold	913	274	1217	333471
Purple	954	174	1586	275947
Orange	735	124	1418	175837
Light Green	605	224	616	137931
Dark Green	660	174	920	160135

Source: Author's Construct, 2012

[18] Nelson and Schrieber in their article, "Smart Parking Revisited: Lessons from the Pioneers" talk of the SFpark in San Francisco which relies on parking sensors, smart meters, and information strategies in its parking management, referred to as the "demand responsive pricing". Los Angeles is also mentioned as being in the process of utilizing these smart meters and sensors in implementing its LA ExpressPark.

Figure 6.4: Annual Parking OM Cost and Revenue Results from the First Simulation



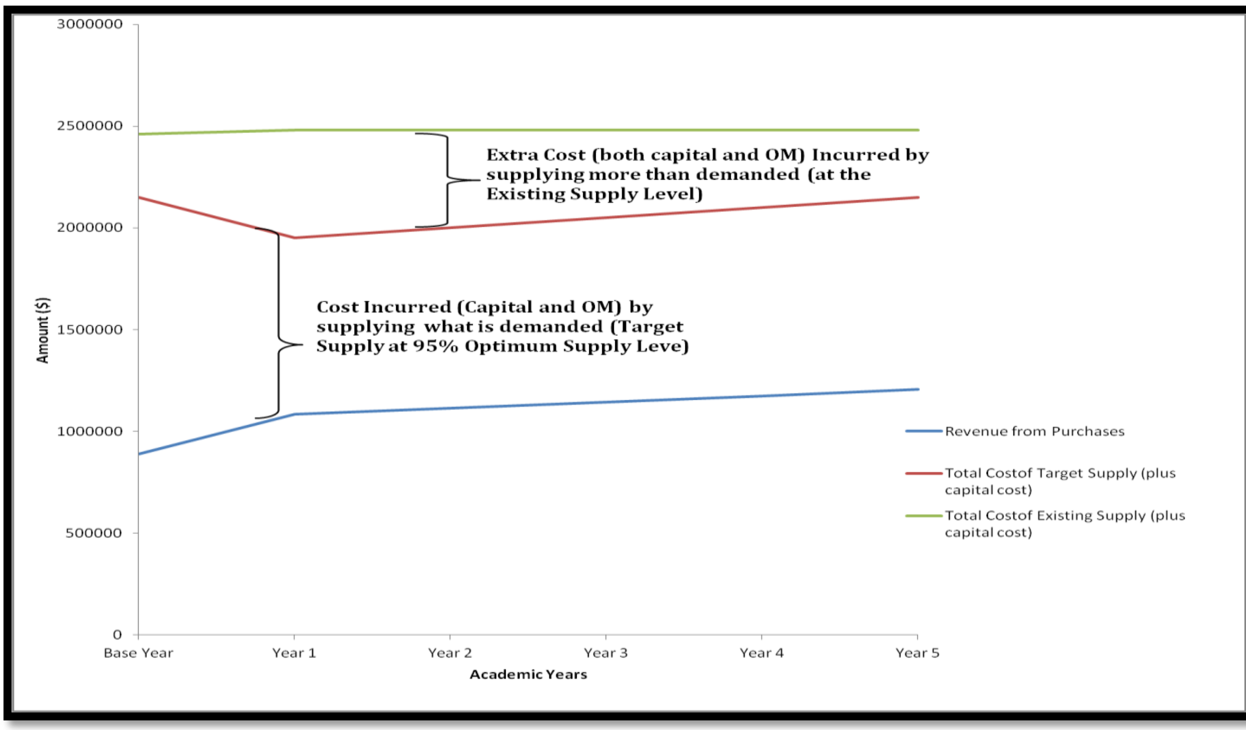
Source: Author's Construct, 2012

C. Demand, Supply, Cost and Revenue Implication of the Hypothesis

When parking spaces are supplied to match what is demanded (i.e. the target supply at the 95% optimum supply level), cost incurred is much lower than supplying at the current fixed supply (see Figure 6.3). In all cases -whether supplying at the target level or at the fixed existing supply level- the cost of parking is higher than the benefits (revenue) derived from it. Consequently, at the prevailing permit price and supply levels, the null hypothesis that “Cost may exceed benefits to meet parking demand" cannot be rejected.

The above conclusion, although germane to the study, is not as apposite as the realization that even though cost may exceed benefits to meet parking demand, those costs could be abated if supply were varied to meet fluctuating demand. This also forms a major reason why future parking policy should aim at using metered parking and sensors to help determine parking demand by each hour of the day, regulate parking prices to adjust supply and demand on campus by the hour, and make parking users pay the full cost of the spaces they use so as to make total cost (capital and OM costs) equal or less than the benefits/revenue generated from parking on campus.

Figure 6.5: Annual Total Parking Cost and Revenue Results from the First Simulation



Source: Author's Construct, 2012

D. Implication of Demand, Supply, Cost and Revenue on Parking Pricing

Prices proposed by the new parking policy, as simulated by the model, will increase annual parking revenue by $29,000 annually. This only satisfies one of the two conditions that parking prices must meet in order to achieve the "optimum parking balance." With parking demand predicted to be less than the existing/current parking supply, and with annual parking revenues being not less than 32% more of the annual parking OM costs, the question, whether permit prices are too high or too low for some permits, should be of concern. Thus, not only can we examine "which price" will better aid in minimizing parking supply surpluses, but we can also assist parking authorities to avoid shifting unnecessary cost burden to users.

To determine the "optimum parking prices," simulations were conducted to adjust the price of each of parking permit to identify which price levels achieve the optimum parking balance; minimize the gap between demand and the existing supply, and generate enough revenue to meet costs. Two of the simulations which approach these solutions are subsequently discussed.

6.3.3 Other Simulation Runs to Increase Parking Demand

A. Simulation Run 1 - Adjusting Parking Permit Prices

- *Parameters for the Simulation*

With this simulation, changes were only made to prices without adjusting any change in supply (see Table 6.3). Below these price levels, parking revenue decreases and may result in making the annual OM cost of the existing supply exceed the revenue see Figure 6.4). The price of gold permits was not changed because of its inelasticity. With gold permits being so close to campus, an increase in price does not have any significant effect of the permits purchased, and hence demand.

- Results from the simulation

Based on such price adjustments, it could be seen from Figure 6.5 that the annual parking supply surplus can be reduced from the maximum and minimum of 21% and 14%

respectively of the existing supply (based on the new University parking policy) to an annual maximum and minimum respectively of 12% and 3% of the existing supply.

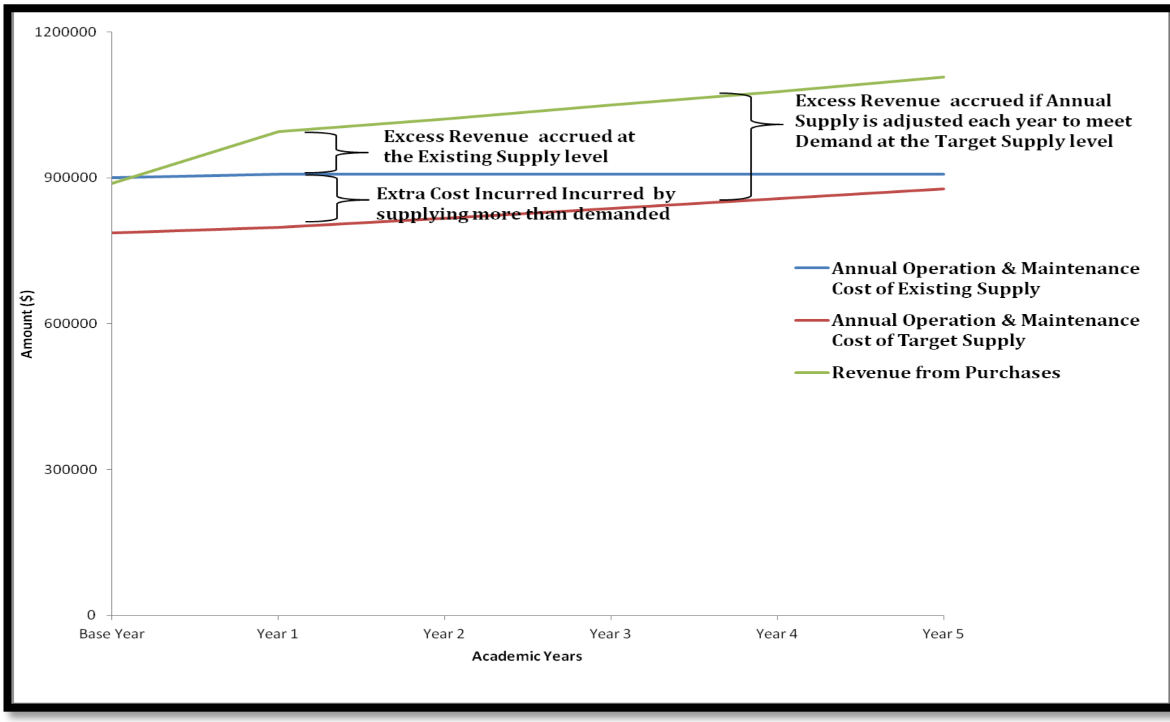
Even though this simulation demonstrates that adjusting prices can help minimize the overall parking supply surpluses without limiting the ability to meet parking costs, it also shows that parking demand for the light and dark green permits will exceed the existing supply as the years progress (see Appendices 24 and 25). However, the demand/peak-use for the gold and purple permits for the entire five years, although increasing, will not exhaust the existing supply. What remains to be done, then, is to reduce the parking supply for gold and purple permits and add these number to that of light and dark green permits. The simulation was run again, shifting the parking supply from the gold and purple to the light and dark green permits.

Table 6.3: Permit Price Changes and Resulting Predictions for Simulation Run 1

Permit Type	Adjusted Prices ($)	New Supply by the New Policy	Predictions for the First Year of Adjustments		
			Demand	Permit Sales Ceiling	Estimated Permit Revenue ($)
Gold	274	913	694	1217	333471
Purple	120	954	724	2057	246840
Orange	90	735	605	1833	164921
Light Green	200	605	547	652	130332
Dark Green	120	660	616	991	118958

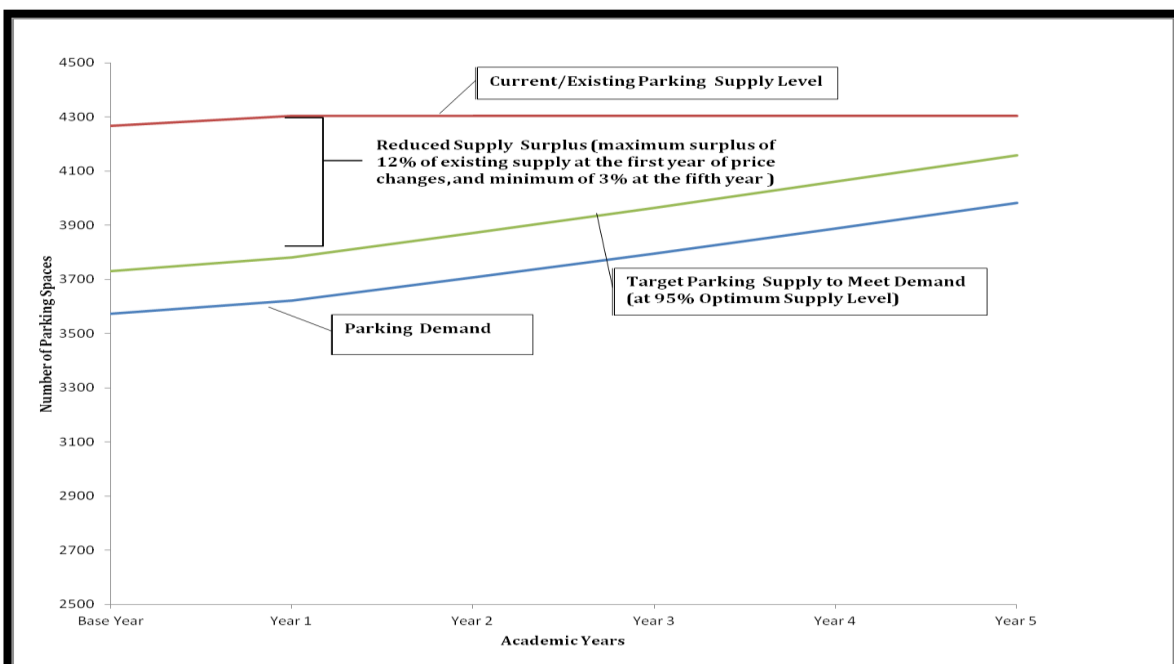
Source: Author's Construct, 2012

Figure 6.6: Annual Parking OM Cost and Revenue Results from Simulation Run 1



Source: Author's Construct, 2012

Figure 6.7: Annual Parking Demand and Supply Results from Simulation Run 1



Source: Author's Construct, 2012

B. Simulation Run 2 - Adjusting Parking Permit Supply

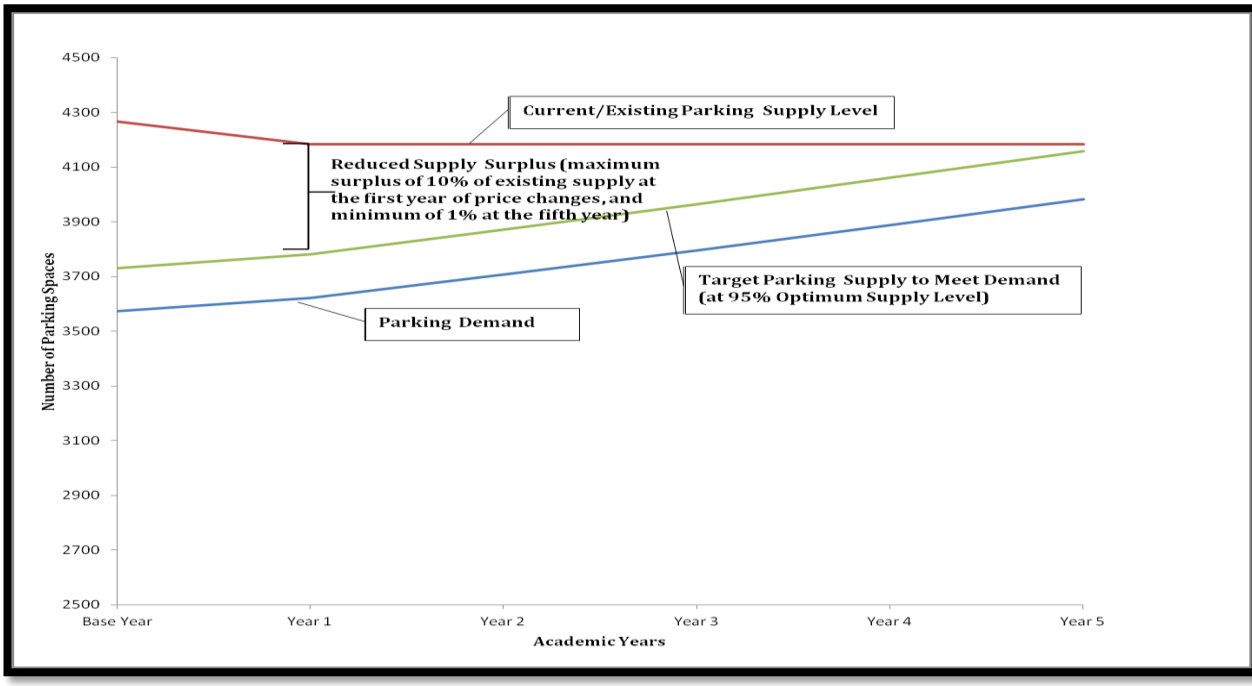
- *The Parameters for the Simulation*

Reducing the excess supply for the gold and purple permits to defray the supply shortages for the light green will not only mean meeting demand, but also will mean cutting down annual OM cost. From the first simulation run, a total of about 220 parking spaces (amounting to $46,420 of annual OM cost) will exceed demand by the fifth year. These excesses are from the gold and purple permits - 80 and 140 spaces respectively. The light and dark green permits will, however, need about 100 spaces (22 for light green and 78 for dark green) by the end of the fifth year to meet growing demand. Hence, after shifting the 100 spaces to the light and dark green permits, a total of $25,320 of OM cost will be saved if the remaining 120 parking spaces were demolished.

- *Results from the Simulation - Demand, Supply, Cost and Revenue Implications*

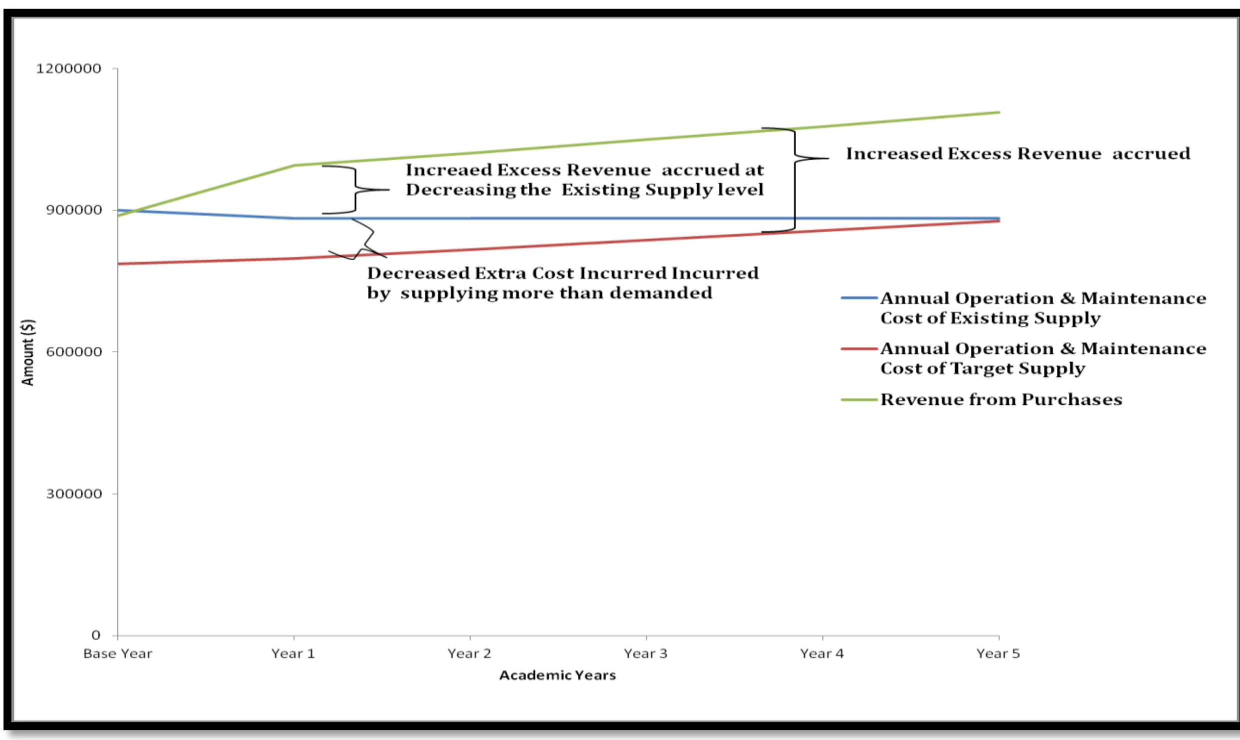
Reducing the supply for gold and purple (see Appendices 26 and 28) and designating some as light and dark green permits spaces (see Appendices 29 and 30), will ensure that all parking permit spaces will meet their demand throughout the five years. Not only that, this measure will further reduce excess parking supply from its maximum and minimum values of 12% and 3% respectively (based on the simulation Run 1) to 10% and 1% (as indicated in Figure 6.6). Futher implication of this measure is that, by decreasing the supply, any resulting decrease in annual OM cost of existing supply imply an annual excess parking revenue of not less than $110, 000.

Figure 6.8: Annual Parking Demand and Supply Results from Simulation Run 2



Source: Author's Construct, 2012

Figure 6.9: Annual Parking OM Cost and Revenue Results from Simulation Run 2



Source: Author's Construct, 2012

6.4 Simulation Summary for Policy Action - The Win-Win Situation for Campus Parking Authority & Parking Users

The model's proposed prices in Table 6.4 are geared towards minimizing the annual supply surplus without jeopardizing the ability to raise enough revenue to at least meet the annual OM cost of parking on campus. With this proposed pricing structure, supply surpluses decreases faster to just 24 excess parking spaces at the end of the five year period. Whereas the pricing structure based on the current University parking policy decreases supply surpluses to only 580 parking spaces (Table 6.5) by the fifth year. The models proposed prices also results in annual net savings of nothing less than $110,000. This, as mentioned earlier, could be used in funding future projects like installing smart parking meters and sensors. These meters would help regulate prices and parking spaces on campus so as to reduce surpluses and shortages, or it could be used to subsidize the construction of a parking ramp at a high-demand location. It can also be used to subsidize the cost of transit on campus and contribute towards achieving MSU's "Green Campus" goal.

Table 6.4: Supply and Pricing

Permit Type	New Policy Changes		Proposed Adjustments Based on Model Simulations	
	Price	Supply	Price	Supply
Gold	274	913	274	833
Purple	174	954	120	814
Orange	124	735	90	735
Light Green	224	605	200	627
Dark Green	174	660	120	738
Total Supply		**3867**	**3747**	

Source: Author's Construct, 2012 based on simulation results and 2012 policy information

Table 6.5: Predictions of Annual Supply and Demand of Parking

Years	Predictions Based on New Policy Prices and Supply				Predictions Based on Model Simulation Prices and Supply (Simulation Run 1 &2)			
	Policy Supply	Demand	Target Supply to meet Demand	Supply Excess/ Surplus	Simulation Supply	Demand	Target Supply to meet Demand	Supply Excess/ Surplus
Base Yr	4267	3574	3731	536	4267	3574	3731	536
Year 1	4303	3244	3385	918	4183	3621	3780	403
Year 2	4303	3321	3466	837	4183	3707	3871	312
Year 3	4303	3401	3549	754	4183	3796	3964	219
Year 4	4303	3482	3635	668	4183	3888	4060	123
Year 5	4303	3566	3723	580	4183	3982	4159	24

Source: Author's Construct, 2012 based on simulation results and 2012 policy information

Table 6.6: Predictions of Annual OM Costs and Revenue of Parking

Years	Predictions Based on New Policy Prices and Supply				Predictions Based on Model Simulation Prices and Supply (Simulation Run 1 &2)			
	Annual OM Cost of Supply	Annual OM Cost of Target Supply	Annual Parking Revenue	Budget Excess/ Surplus	Annual OM Cost of Supply	Annual OM Cost of Target Supply	Annual Parking Revenue	Budget Excess/Surplus
Base Yr	900337	787307	889375	-10962	900337	787307	889375	-10962
Year 1	907933	714202	1083320	175387	882613	797663	994522	111909
Year 2	907933	731275	1112650	204717	882613	816795	1021490	138877
Year 3	907933	748848	1142840	234907	882613	836483	1049240	166627
Year 4	907933	766935	1173900	265967	882613	856744	1077810	195197
Year 5	907933	785553	1205870	297937	882613	877596	1107200	224587

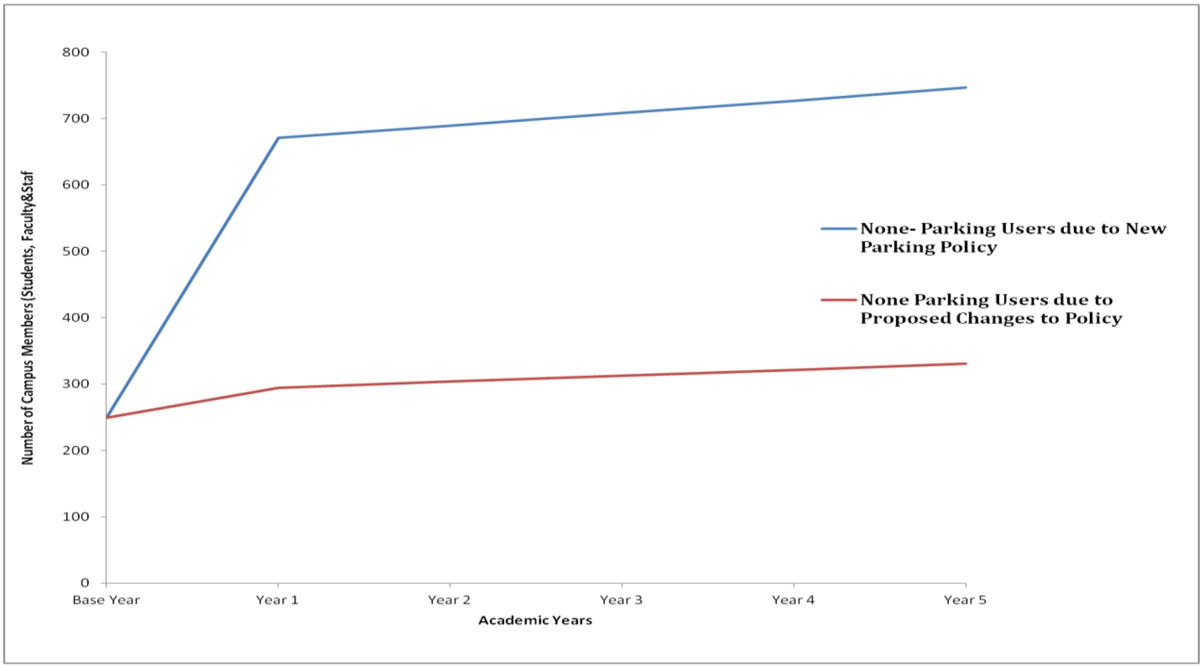
Source: Author's Construct, 2012 based on simulation results and 2012 policy information

6.5 Transit and Parking Interdependence

As earlier indicated, the models attribute most of the changes in parking demand to price and not to the provision of transit on campus. This was informed by the 2011 Greater Mankato Transit Study (URSI, 2011) which realized that campus members (mostly the off-campus ones), prefer coming to campus with their own vehicles rather than using the buses or carpooling. Particularly with the buses, the issue is not primarily one of choice but one of necessity. The limitations in bus routes, days and hours of operation make it impossible for many people to consider using the buses to and from campus.

From the simulations, as presented in Figure 6.8, it is expected that the new price increases will increase the number of campus members who will no longer be interested in paying for the use of parking spaces. However, with the proposed changes, that number will be cut in half. These people will join other campus members who are already using the bus and other forms of transportation to and from campus (carpooling/sharing, bicycles/motorbikes, walking, etc). Future study will be needed to examine the impact of the "GTF" on parking demand on campus.

Figure 6.10: Changes to Non-Parking Users resulting from Parking Price Changes



Source: Author's Construct, 2012

CHAPTER SEVEN

SUMMARY OF MAJOR FINDINGS, RECOMMENDATIONS AND CONCLUSION

7.1 Introduction

The primary aim of this study was to consider the relationship between parking demand and supply on campus, and to determine the cost and benefits implications of campus parking policies. This was achieved by developing a dynamic model of parking economics to study the components and trends in demand and supply and the "optimum parking price" which will ensure the optimal parking balance.

This Chapter offers a summary of these results, discussing them in the context of the aims of the research. Based on these summary findings, recommendations, targeted at both long and short-term policy actions for campus parking policies are then offered.

7.2 Summary of Major Findings

- ***Parking Occupancy and Peak Periods***

Parking occupancy for campus surface lots peaks between the hours of 10am to 2pm. Within this period as many as 688 vacant spaces (18% vacancy rate) are scattered around the campus. With the exception of the designated dark green parking lots, all the other designated paid parking areas record nothing less than 15% vacancy rate at their peak periods. As expected, the free lot spaces are full during these peak periods.

❖ *Demand and Supply Relationship*

Parking demand also referred to as the "Peak Use," measures the total number of parking spaces/supply occupied at the peak period. Even though each parking space is sold at the beginning of an academic year/semester to at least one parking user, parking supply is not exhausted, even at the peak periods, except for the dark green and the free lots.

Notwithstanding these parking supply excesses, MSU's parking demand trend, based on data from the 2002 to 2011 academic years, shows that demand has generally been increasing since the 2006/2007 academic year. Demand only decreased in 2005/2006, and the increase slowed in 2007/2008 with the introduction of new prices. With the percentage price increase in 2005/2006 being much higher (not less than 9.5% for each permit) than that of 2007/2008 (maximum increase of 2.9%), the behavior of the demand trend for these two periods were different.

The relationship between campus parking prices and alternative campus transportation modes (particularly the bus transit system) also had an impact on parking demand. It is therefore expected that improving the bus transit service (in terms of lower fares, increased service hours and days, as well as improving bus routes) may have much impact (possibly a decreasing effect) on parking demand), especially if such improvements coincide with increased parking prices.

❖ *Parking Costs, Permit Pricing and Benefits on Campus: Cost Excesses & Subsidization Issues*

Meeting the annual parking demand on campus results in at least $211 to $366 (annualized at rate of 3% for 10 years) as the annual Operations & Maintenance (OM) cost and capital cost per parking space respectively on campus. The capital cost includes construction and land costs. The cost of land on campus is estimated annually at $68 per parking space. This value represents the environmental value for every parcel of land used for parking, and is measured by the rent that the University could have generated if it had either sold the land or used it for commercial purposes.

Paving the surface for parking not only reduces the aesthetic quality, and hence the environmental value, of the land but it also carries an extra cost to the University since storm water, which hitherto percolated through the unpaved soil, now has to be managed. Whether it is worth diminishing $68 of land per parking space and spending an average $211 annually to operate and maintain it, depends on the price that the space commands annually.

Given that (except for the price of gold permits in 2002/2003) parking prices were even less than the annual OM costs per parking space, it can safely be assumed that it is not worth it. Hence, with an annual cost-benefit ratio of either 0.5 or 0.4 for all years, cost of parking is always twice more the benefits derived on campus. Thus, parking cost was determined to be more than benefits if parking demand is met.

❖ ***Cost Excesses***

Since supply was identified as exceeding demand, parking cost was therefore seen to be higher than what is should have been if supply were limited to only that which is demanded. However, with demand increasing, the cost of supply in excess of demand was shown to have decreased to $56,000 in 2010/2011, down from $77,000 in 2009/2010.

❖ ***Cost Subsidization Issues***

Annual OM cost of parking exceeded revenue in 2004, 2006, 2008, 2010 and 2011 fiscal years. The use of parking funds to subsidize the cost of Mankato bus transit on campus was cited as a major factor for such deficit and hence the "Green Transportation Fee" was introduced in 2012 to make campus transit pay for its cost.

❖ ***Parking Model and Simulation Results: Identifying the Optimum Parking Price***

A model of parking as a system of interrelated components was developed to help answer the question of whether cost exceeds benefits when parking demand is met. Using the newly introduced (2012) MSU parking policy on permit prices and supply as inputs for the model, simulations were run to determine a five year prediction of the policy's impact on demand, supply, cost and benefit.

The first simulation run confirmed what earlier analysis observed, that the annual total cost of parking always exceeded the benefits derived. The cost could be minimized however, if planned parking supply is modified and targeted at meeting demand (with at most 5% extra spaces). In other words, a prolonged fixed supply (as it is mostly the case in MSU) coupled with infrequent determination of demand, will widen the gap between parking cost and revenue.

Two other simulation runs were then used to determine optimal permit prices and supply, given the new policy changes. Holding the price steady for two permit categories but decreasing the prices for all other categories could still generate enough revenue to meet annual OM cost without putting as heavy a cost burden on parking users. The simulation also demonstrated that decreasing the total supply by 120 spaces could minimize annual parking supply surpluses from the initial maximum and minimum values of 21% and 14% respectively (observed for from the simulations with the new policy inputs), to new maximum and minimum values of 10% and 1% respectively. Such supply minimizations would result in $110,000 annual net savings in parking costs.

❖ ***Transit and Parking Interrelationships***

The increase in parking prices (as proposed by the University's new parking policy), doubling in number choosing not to park on campus is expected to increase the number of campus members who don't want to pay in the increase. It does not necessarily mean that these people will choose a different mode of transport - some of them will still drive to campus, but park at free spots in the neighborhood (or in the free lot). Based on the model's proposed prices however, this number will reduce by two thirds. These changes are primarily attributable to parking prices and not necessarily the "free" bus passes.

The current transit service provided by the Greater Mankato buses may limit the substitution between parking demand and transit. In the 2011 Greater Mankato Transit

Study (URSI, 2011), students, faculty and staff at MSU indicated their willingness to increase their bus ridership if service quality were improved. Therefore, even with the introduction of the "GTF", parking demand may only respond to changes in prices and not the "free" bus passes introduced.

7.3 Meeting Parking Demand at Less Cost and More Benefits: Recommendations for Policy Action

There is a tendency to increase parking supply on campus to satisfy anticipated increases in demand. As observed however, such supply increases only end up increasing supply surplus, with associated excess cost. Therefore, short-term measures in meeting demand at less cost should consider the following:

A. Directing the Parking Supply "Shift-Share" Policy at Annual Demand Targets: The overall supply does not need to be increased. Instead, the practice of changing (increasing or decreasing) the supply for permits only when prices are being introduced should rather be an annual policy exercise for the University's Parking Authorities. To do this:

- Demand and permit purchase predictions would have to be done at the end of each academic year to determine possible demand estimates for each parking permit for the following year. The prediction for the demand should rely on parking occupancy counts of peak period uses for each parking permit;
- With the predicted demand levels, supply for each parking permit group can then be adjusted by re-designating existing parking spaces.

This policy measure will help minimize parking surpluses for each parking permit group by making sure that annual designation of parking spaces for each parking permit are solely based on its predicted demand and not necessarily on purchases because increased purchases does not necessarily translate to increased demand (peak use).

B. Complementing Annual Parking Demand and Supply Changes with Price Changes

Prices should not only change (increase) if predicted parking OM cost is expected to exceed predicted revenue. Permit prices should also change if authorities want to influence parking demand through purchases. For instance;

- ❖ When annual demand predictions show greater increases than what existing supply can meet, prices may be increased to reduce permit purchases such that, even if all purchased permit users would have to be presented at the peak time (demand), there will be enough spaces for them. In the case of the gold permit users, who barely respond to price changes, an increase in price will only mean an increase in revenue, unless annual OM cost of gold lots increases.
- ❖ Conversely, when annual predictions show demand and purchase decreases to the extent that annual OM cost for the permit in question will exceed revenue, then prices may be decreased to a level which results in revenue increases to the level necessary to meet annual OM costs.

This policy measure introduces the "optimum parking price" as part of MSU’s short-term policy measures. Both policy measures (a and b) would require predictive models, such as the one proposed in this study.

Implementing the above short-term measures is one efficient means of dealing with the issue of meeting parking demand at less cost. The long-term measure, which will be both efficient and sustainable, should focus on regulating demand, supply and pricing on daily basis instead of a semester or annual basis using electronic meters, sensors, and information strategies

7.4 Recommendations for Future Research

Future research can consider the impact of "free" bus ridership on campus parking demand. Data from transit ridership for the upcoming semester can be analyzed to establish whether the "free" bus passes had any significant impact on parking demand. The relationship can therefore be used to revise the parking model.

Again, future studies can also look at the impact of parking prices and "free" bus passes on parking demand for the outlying parking lots. The result from such studies will be useful in examining the prospects in relocating all parking facilities to the fringes of MSU campus. This is to serve as a measure of determining the feasibility of achieving the third goal of MSU's Campus Sustainability Plan (2010-2035) of;" Decreasing the visual and spatial impact of surface parking on campus" (URSI, 2010).

With these research additions, parking policy on campus will then have an integrative and holistic way of making parking policies and transit provision on campus complement each other. Parking policy measures could then be planned such that the minimum cost will be incurred (economic and environmental), but still generate the maximum benefits for the University

7.5 Conclusion

In meeting parking demand on campus, the cost usually exceeds the benefits due to cost excesses and what Shoup (2008) refers to as "faulty pricing". When campus parking demand is expressed in terms of anticipated annual permit purchases and or students enrolment only, it leads to the oversupply of parking spaces (mostly the case of the orange and purple permits) or their undersupply (also mostly the case of the dark green permits). The oversupply results in annual cost excesses while the undersupply results in peak use congestion on the lots, which makes it look as though more parking spaces should be constructed, thereby further increasing the cost of parking.

Normally, such oversupply and undersupply is closely tied with the issue of pricing being too high (for the orange and purple permits) or too low (for the dark green permit). Revenue generated as a result of such high prices justifies their supply. However, their prices could have been much less and still have generated enough revenue if supply were tailored to minimize supply surpluses.

The recognition that "Cost may exceed benefits, if parking demand is met" is a challenge to the status quo of campus parking and transportation planning in light of the global call for creating a more sustainable environment. Due to the limited transit service in Mankato, the use of private vehicles is more of a necessity than a choice, especially for campus members who have to commute to campus. Even residential students (commonly First-Year students) are concerned about the availability of safe parking spaces when choosing where to further their education. The parking challenges for school authorities are enormous since there is the construction phase and the maintenance phase of these facilities which all have their commensurate cost attached.

In MSU not only are we trying to meet increasing parking demand, we are also trying to meet this demand at the minimum price to parking users. Not only that, we are trying to meet parking demand while making sure that we do not compromise the quality of the environment by unnecessarily paving our lands and destroying our green surroundings. As the study demonstrates, there is still hope of satisfying all these seemingly insatiable quests, if pricing is used as a tool for controlling parking demand and supply.

The parking model developed in this study not only validates the assertion that cost exceeds benefits at MSU, it also offers a platform for predicting parking demand for a five year period, helps in determining what the target should be, and helps identify what the "right price" should be in generating enough parking revenue to at least meet the annual OM cost of parking.

LIST OF REFERENCES

Cervero, R. (2001). Induced Demand: An Urban and Metropolitan Perspective. A paper prepared for *Policy Forum: Working Together to Address Induced Demand.* Retrieved on 11/04/2012 from www.uctc.net/papers/648.pdf.

Chapra, M. U. (1991). The Need For A New Economic System, Review of Islamic Economics. *Journal of the Islamic Economic Association*. Published from Leicester, UK). Vol. 1, No.1, 1991, pp.9-47.

Craswell, G. (2005). Writing for Academic Success: A Postgraduate Guide. SAGE Publications, ISBN1412903009 and 9781412903004.

Dober, R.P. (1996). Campus Architecture: Building in the Groves of Academe. NY: McGraw Hill.

FHWA (2004). Travel Demand Management. Retrieved on 11/04/2012 from http://www.ops.fhwa.dot.gov/aboutus/one_pagers/demand_mgmt.htm

FTA (2002). Transit Performance Monitoring System (TPMS) Results, American Public Transit Association(www.apta.com) and the Federal Transit Administration (www.fta.dot.gov/transit_data_info/reports_publications/reports/16031_ENG_HTML.htm).

Hills, P. (1996), "What is Induced Traffic?" *Transportation*, Vol. 23, No. 1, pp. 5-16.

Kuzmyak, J. R., Weinberger, R., and Levinson, S. H. (2003). Parking Management and Supply: Traveler Response to Transport System Changes. Chapter 18, Report 95, Transit Cooperative Research Program; TRB (www.trb.org).

Litman, T. (2002). Evaluating Transportation Land Use Impacts. *Victoria Transport Policy Institute*. Retrieved on 05/10/2012 from www.vtpi.org/landuse.pdf.

Litman, T. (2011). Parking Pricing Implementation Guidelines: How More Efficient Parking Pricing Can Help Solve Parking And Traffic Problems, Increase Revenue, And Achieve Other Planning Objectives. *Victoria Transport Policy Institute* ,1 March 2011. Retrieved on 05/10/2012 from www.vtpi.org

Litman, T. (2012a). Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior. *Victoria Transport Policy Institute*, 23 April 2012. Retrieved on 05/10/2012 from www.vtpi.org

Litman, T. (2012b). Parking Management: Strategies, Evaluation and Planning. *Victoria Transport Policy Institute*, 26 July 2012. Retrieved on September 11, 2012 from www.vtpi.org

Litman, T. (2012c). Generated Traffic and Induced Travel: Implications for Transport Planning. *Victoria Transport Policy Institute, 10 September, 2012.* Retrieved on September 20, 2012 from www.vtpi.org/gentraf.pdf.

Manville, M., and Shoup, D. (2005). People, Parking, and Cities. *Journal Of Urban Planning And Development*, American Society of Civil Engineers (www.asce.org), December, pp. 233-245. Retrieved on 17/05/2012 at http://shoup.bol.ucla.edu/People,Parking,Cities JUPD.pdf; in Access 25 (www.uctc.net), Fall 2004, pp. 2-8.

Martens, M., and van Luipen., B. (2009). To a Better Future with a Motivated Parking Tariff: Practical Applications for an Economic Based Parking Tariff. *World Parking Symposium*, Breda, 2009, June 29th.

Mokhtarian, L., P. (2004). Understanding the Concept of Latent Demand in Traffic. Retrieved on 11/04/2012 from www.dot.ca.gov/researchconn/.../induced _demand_powerpoint.ppt

MRSC (2005). Parking Demand and Pricing. Municipal Research and Service Center of Washington. Retrieved on 05/17/2012 at www.mrsc.org/subjects/transpo/ pkgdemand.aspx

Nelson, J. and Schrieber, J. (2012). Smart Parking Revisited : Lessons from the Pioneers. *APA Planning Magazine*, *Vol. 78*, 25-29

Pratt, R. (1999). Traveler Response to Transportation System Changes, Interim Handbook. TCRP Web Document 12, DOT-FH-11-9579, National Academy of Science (www4.nationalacademies.org/trb/crp.nsf/all+projects/tcrp+b-12).

Regidor, J. R. F. (2006). A Review of Trip and Parking Generation Rates in the Philippines. *Philippine Engineering Journal.* PEJ 2006; Vol. 27 No. 1:1–12. Retrieved on 05/17/2012 from http://journals.upd.edu.ph/index.php/pej/article /view/18001717

Rodier, J. C. (2004). A Review of the Representation of Induced Highway Travel in Current Travel and Land Use Models. Paper submitted to Transportation Research Board (TRB). Retrieved on 11/04/2012 from www.its.ucdavis.edu/wp-content/themes/.../download_pdf.php?id..

Shoup, D. (1999). In Lieu of Required Parking. *Journal of Planning Education and Research*, Vol. 18, No. 4, Summer 1999, pp. 307-320.

Shoup, D. (2005 and 2011). The High Cost of Free Parking. Planners Press, Chicago.

Shoup, D. (2008). The Politics and Economics of Parking on Campus. in Stephen Ison and Tom Rye (eds.), Transport Demand Management Measures: An International Perspective, 2008, pp. 121--149.

Shoup, D., and Pickrell, D (1978). Problems with Parking Requirements in Zoning Ordinances. *Traffic Quarterly*, Vol. XXXII, No. 4, October 1978, pp. 545–563.

Stigler, G. (1941). Production and Distribution Theories: The Formative Period. Macmillan: New York.

Topp, A. C., (2009). Arapahoe County Parking Utilization Study Concerning Residential Transit Oriented Development. School of Public Affairs, University of Colorado Denver. Retrieved on 05/10/2012 at www.vtpi.org/topp_parking.pdf.

Tumlin, J. (2012). Sustainable Transportation Planning: Tools for Creating Vibrant, Healthy, and Resilient Communities. John Wiley and Sons Inc. Hoboken, New Jersey. ISBN-10: 0470540931; and ISBN-13: 978-0470540930.

VTPI (2011). Online TDM Encyclopedia. Retrieved on 05/10/2012 from http://www.vtpi.org/tdm/index.php.

VTPI (2012). Transportation Cost and Benefit Analysis II – Parking Costs. Victoria Transport Policy Institute. Retrieved on 05/10/2012 at www.vtpi.org/tca/tca0504.pdf

Willson, R. (1997). Parking Pricing Without Tears: Trip Reduction Programs. Transportation Quarterly, Vol. 51, No. 1, Winter 1997, pp. 79-90.

Woudsma, C., Litman, T., and Weisbrod, G. (2006). A Report On The Estimation Of Unit Values Of Land Occupied By Transportation Infrastructures In Canada, Transport Canada. Retrieved on 05/10/2012 at www.tc.gc.ca/pol/en/aca/fci/transmodal/menu.htm.

APPENDICES

Appendix 1: Off-Street Parking Occupancy Survey Instrument

Time	**Number of Vehicles Parked**					
	Lot 1	**Lot 4**		**Lot 5**	**Lot 6**	**Lot 7**
	Gold Permit	**Gold Permit (Lot 4a)**	**Visitor s**	**Gold Permit**	**Gold Permit**	**Gold Permit**
8-9am						
9-10am						
10-11am						
11-12 noon						
12-1pm						
1-2pm						
2-3pm						
3-4pm						
4-5pm						

Time	Number of Vehicles Parked							
	Lot 8	**Lot 11**	**Lot 11 a**	**Lot 16**			**Lot 20**	**Lot 20 a**
	Gold	**Gold**		**Gold**	**Green**	**Visitors**	**Purple**	**Dark Green**
8-9am								
9-10am								
10-11am								
11-12 noon								
12-1pm								
1-2pm								
2-3pm								
3-4pm								
4-5pm								

Time	Number of Vehicles Parked					
	Lot 21 North	**Lot 21 South**		**Lot 22 North and South**		**Free lot**
	Purple	**Dark Green**	**Orange**	**Orange**	**Brown**	
8-9am						
9-10am						
10-11am						
11-12 noon						
12-1pm						

1-2pm						
2-3pm						
3-4pm						
4-5pm						

Appendix 2A: On-Street Metered Parking Turnover Counts

Name of Road ....
Start Point ....   End Point ....
Approximate Length (meters) ....
Number of Lots: Left ....   Right ....

8:00 - 8:30	8:30 - 9:00	9:00- 9:30	9:30-10	10-10:30	10:30-11	11-11:30	11:30-12

Appendix 2B: On-Street Metered Parking Occupancy

Name of Road ....
Start Point ....   End Point ....
Approximate Length (meters) ....
Number of Lots: Left ....   Right ....

Time	**Number of Vehicles Parked**						**TOTAL**
	Gold		Green		Other color (specify)		
	Left	Right	Left	Right	Left	Right	
6-7am							
7-8am							

8-9am

9-10am

10-11am

11-12 noon

12-1pm

1-2pm

2-3pm

3-4pm

4-5pm

5-6pm

6-7pm

Appendix 3: Interview Guide for Meeting with MSU Parking and Facilities Director.

EXISTING PARKING SITUATION ON CAMPUS

A. Determining Parking Supply and Permit Value

1. What indicators are used in determining how many parking spaces to be supplied?

....

2. What criteria are used in determining the value (prices) of the parking permits on campus?

....

B. Parking Violations

3. What parking violations do you normally address?

....

4. What might be the possible causes of these violations?

....

5. How do these violations affect MSU's Parking?

....

6. Aside violators being made to pay fines, how else do you deal with these violations?

....

C. Parking Demand in MSU

7. How has MSU managed past and existing parking demands?

....

8. What factors might have accounted for changes in parking demand on campus?

....

9. What factor(s) might lead to an increase/decrease in parking demand?

Factors for Increase	Factors for Decrease

Other Comments

....

<u>MEETING FUTURE DEMAND</u>

10. Should there be future increase, will your plan for meeting such increase imply any of the following please tick any of these answers which apply and answer the subsequent question):

a. Converting undeveloped lands into parking facilities ( )
b. Converting existing land uses into parking facilities ( )
c. Expanding existing parking facilities ( )
d. Maintaining existing supply and using pricing to meet demand ( )
e. Other option please specify ( )

If "a" and or "b", please specify the areas and the estimated number of parking spaces to be added

....

If "c", which parking lots can be expanded and how many spaces can be added to the existing supply?

....

If "d" please specify the prices for the various parking permits you think will be suitable

....

MEETING FUTURE DEMAND AND IMPLICATIONS FOR REVENUE, TRANSIT AND GREEN CAMPUS AGENDA

11. How will any of your choices above increase parking revenue without increasing short and long term cost (economic and environment) to MSU?

....

12. How can your choice (s) improve transit on campus?

....

13. How does any of your choice(s) in the above question contribute in achieving the Green Campus Agenda?

....

Other Comments

....

Appendix 4: Number of Resident Students who Purchase Permits

Academic Years	Total Number (X)	Number who purchase permits (Y)
2011/2012	3,296	2134
2010/2011	3,233	2371
2009/2010	3,082	2266
2008/2009	3,073	2207
2007/2008	2,820	2009
2006/2007	2,626	1839
2005/2006	2,681	1887
2004/2005	2,709	1912
2003/2004	2,830	2018
2002/2003	2,832	2020

Appendix 5: Number of Non-resident Students who Purchase Permits

Academic Years	Total Number (X)	Number who purchase permits (Y)
2011/2012	10,602	2968
2010/2011	10,693	3429
2009/2010	10,777	3350
2008/2009	10,666	3221
2007/2008	10,959	3496
2006/2007	10,875	3441
2005/2006	11,004	3526
2004/2005	10,960	3497
2003/2004	10,733	3347
2002/2003	10,485	3183

Appendix 6: Number of Faculty/Staff who Purchase Permits

Academic Years	Total Number (X)	Number who purchase permits (Y)
2011/2012	1464	1306
2010/2011	1,525	1,408
2009/2010	1,580	1,475
2008/2009	1,632	1,437
2007/2008	1,608	1448
2006/2007	1,536	1428
2005/2006	1,498	1417
2004/2005	1,460	1407
2003/2004	1,407	1392
2002/2003	1,377	1383

Appendix 7: Parking Supply in MSU

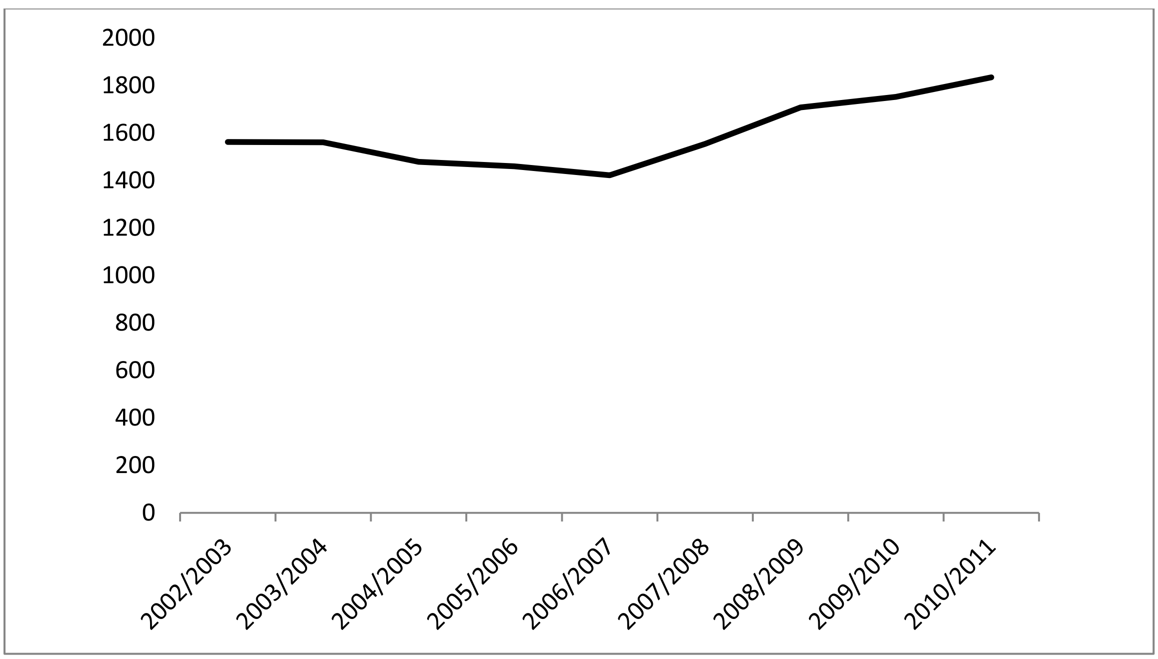
Academic Years	Total Number of Parking Spaces									
	Gold	Orange	Purple	Light Green	Dark Green	Free Lot	**Total**	**Other Spaces**	**Total plus other spaces**	**Minus free lot**
*2012/2013	913	735	954	605	660	436	**4303**	860	5163	4727
2011/2012	943	563	618	1213	494	436	**4267**	860	5127	4691
2010/2011	943	688	618	1298	369	436	**4352**	860	5212	4776
2009/2010	943	735	618	1222	322	436	**4276**	860	5136	4700
2008/2009	935	735	618	1230	322	436	**4276**	860	5136	4700
2007/2008	935	735	618	1230	322	436	**4276**	860	5136	4700
2006/2007	940	735	618	1230	322	436	**4281**	860	5141	4705
2005/2006	922	735	657	1230	322	436	**4302**	860	5162	4726
2004/2005	911	735	672	1230	322	436	**4306**	860	5166	4730
2003/2004	883	1126	464	1230	322	436	**4461**	860	5321	4885
2002/2003	768	1126	464	1230	322	436	**4346**	860	5206	4770

*This is proposed parking supply according to the 2012-2013 "Post Hearing" Sheet by the Parking Advisory Committee, MSU.

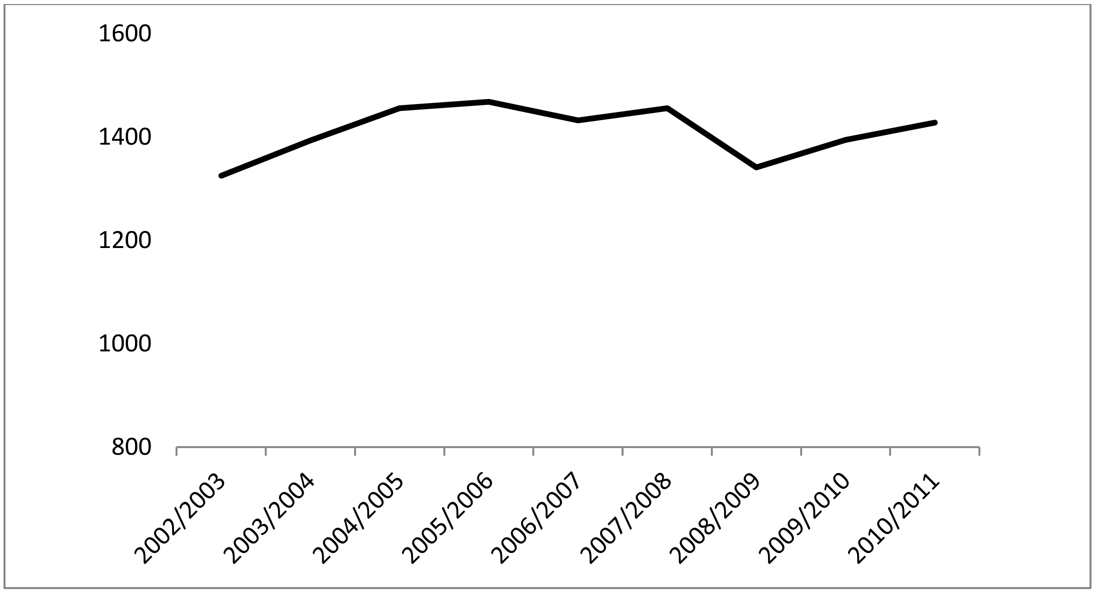
Appendix 8: Ratio of Parking Permits to Parking Spaces

Academic Years	Resident Students			Non-Resident Students & Faculty/Staff		
	Permits	Supply	Ratio of permits to spaces	Permits	Supply	Ratio of permits to spaces
2010/2011	2371	1667	1.4	4837	2249	2.2
2009/2010	2266	1544	1.5	4825	2296	2.1
2008/2009	2207	1552	1.4	4658	2288	2.0
2007/2008	2009	1552	1.3	4944	2288	2.2
2006/2007	1839	1552	1.2	4869	2293	2.1
2005/2006	1887	1552	1.2	4943	2314	2.1
2004/2005	1912	1552	1.2	4903	2318	2.1
2003/2004	2018	1552	1.3	4738	2473	1.9
2002/2003	2020	1552	1.3	4566	2358	1.9

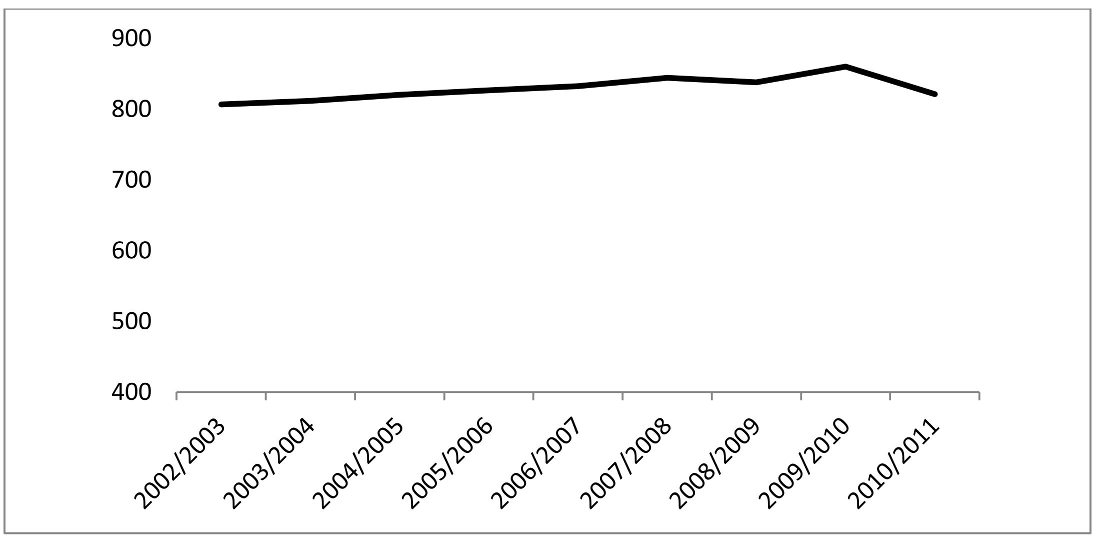
Appendix 9: Parking Demand Trend for Resident Students



Appendix 10: Parking Demand Trend for Non-resident Students



Appendix 10: Parking Demand Trend for Faculty/Staff



Appendix 11: Comparing the Beta Values for Regression Analysis - Resident Students

	Beta Value of Y on:		Percentage Change from Previous Values
	X 1 only	2.21	-
	X 2 only	12.09	-
	X8 only	0.96	-
X1 and X2	X1	1.61	27% Decrease
	X2	9.19	24% Decrease
X1, X2 and X6	X1	-0.039	101.8% Decrease
	X2	-0.014	100.1% Decrease
	X6	0.965	0.5% Increase

The Best Regression Model Using the Three Variables:

Parking Demand (Y) for Resident Students = -0.039X1 -0.014X2 + 0.965X6 -297.315

where:

X1= Number of Parking Spaces Supplied/Available to Resident Students

X2= Parking Fees/Price Paid by Resident Students

X6 = is the summation of all the parking substitutes available to resident students (X3, X4, and X5)

X3= The number of resident users who use transit (buses) to and for movement on campus;

X4= The number of resident users who walk to and for movement on campus

X5= The number of resident users who use bicycles/motorbikes to and for movement on campus.

Appendix 12: Comparing the Beta Values for Regression Analysis - Non-resident Students

Beta Value of Y on:		Percentage Change from Previous Values
X 1 only	-0.209	-

	X 2 only	-0.421	-
	X8 only	0.353	-
X1 and X2	X1	-0.465	123% Increase
	X2	-2.661	532% Increase
X1, X2 and X8	X1	-0.120	43 % Decrease
	X2	-0.586	39% Increase
	X8	0.337	5% Decrease

The Best Regression Model Using the Three Variables:

Parking Demand (Y) for Non-resident Students = -0.120X1 + -0.586X2 + 0.337X8 - 1013.198

where:

X1= Number of Parking Spaces Supplied/Available to Non-resident students

X2= Parking Fees/Price Paid by Resident Students

X8 = is the summation of all the parking substitutes available to non-resident students (X3, X4, X5, X6, X7 and X8)

X3= The number of non-resident users who use transit (buses) to/from and for movement on campus;

X4= The number of non-resident users who walk to/from and on campus

X5= The number of non-resident users who use bicycles/motorbikes to/from and on campus.

X6= The number of non-resident users who use carpool/sharing to/from and on campus.

X7= The number of non-resident users who are dropped off/picked up to/from and from campus.

Appendix 13: Comparing the Beta Values for Regression Analysis - Faculty/Staff

Beta Value of Y on:		Percentage Change from Previous Values
X 1 only	-0.136	-
X 2 only	1.317	-
X8 only	0.348	-

X1 and X2	X1	-0.02	85% Decrease
	X2	1.23	7% Decrease
X1, X2 and X8	X1	0.033	124% Decrease
	X2	0.083	94% Decrease
	X8	0.368	6% Increase

The Best Regression Model Using the Three Variables:
Parking Demand (Y) for Faculty/Staff = 0.033X1 + 0.083X2 + 0.368X8 + 462.339

where:

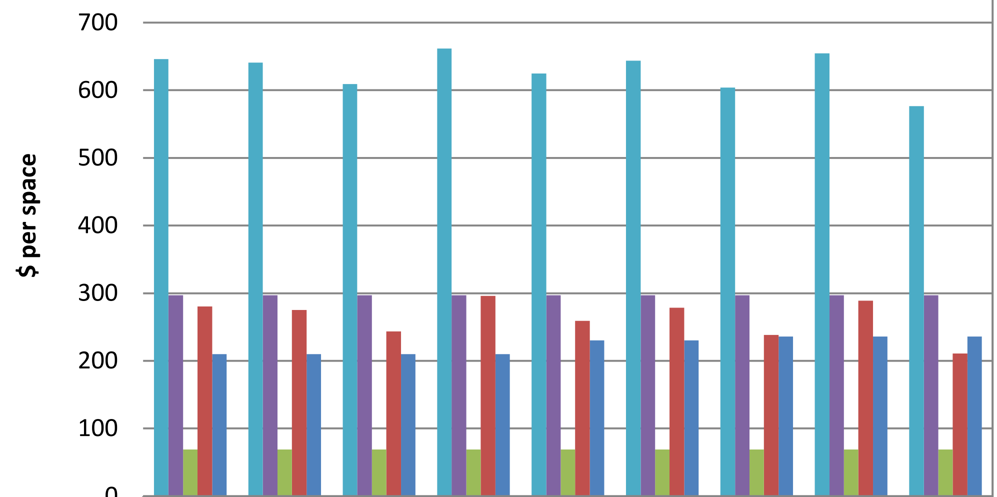
X1= Number of Parking Spaces Supplied/Available to Faculty/Staff
X2= Parking Fees/Price Paid by faculty/staff
X8 = is the summation of all the parking substitutes available to faculty/staff (X3, X4, X5, X6, X7 and X8)
X3= The number of faculty/staff users who use transit (buses) to and from campus;
X4= The number of faculty/staff users who walk to and from campus
X5= The number of faculty/staff users who use bicycles/motorbikes to and from campus.
X6= The number of faculty/staff users who use carpool/sharing to and from campus.
X7= The number of faculty/staff users who are dropped off/picked up to and from campus.

Appendix 14: Cost per parking space in MSU

Academic Year	Annual Operating Cost			Capital Cost ($) Per Space/Stall ().			Total Annual Cost ($ per space)
	Operating Cost ($)	Total Parking Spaces ($)	Annual Operating Cost ($ per space)	Annualized Land Cost Per Space	Annualized Construction Cost ($ per space)	Total Capital Cost ($ per space)	
2010/2011	$1,097,868	5,212	$211	$68.86	$297	$366	$576
2009/2010	$1,484,508	5,136	$289	$68.86	$297	$366	$655
2008/2009	$1,223,982	5,136	$238	$68.86	$297	$366	$604
2007/2008	$1,429,06	5,136	$278	$68.86	$297	$366	$644

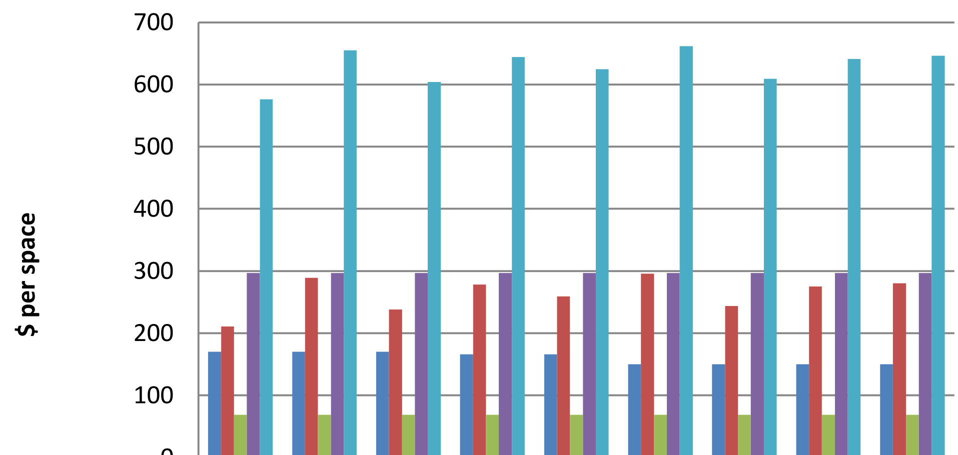
	9						
2006/2007	$1,331,636	5,141	$259	$68.86	$297	$366	$625
2005/2006	$1,527,378	5,162	$296	$68.86	$297	$366	$662
2004/2005	$1,258,570	5,166	$244	$68.86	$297	$366	$609
2003/2004	$1,465,279	5,321	$275	$68.86	$297	$366	$641
2002/2003	$1,459,479	5,206	$280	$68.86	$297	$366	$646

Appendix 15: Comparing Costs and Pricing for Parking Space - Gold Permits



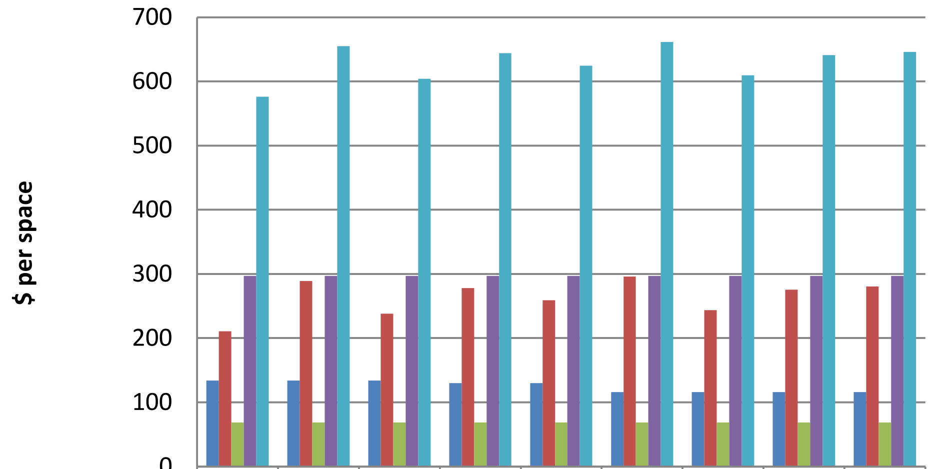
	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
Gold Annual Price/Fees	210	210	210	210	230	230	236	236	236
Gold Annual Operating Cost	280	275	244	296	259	278	238	289	211
Gold Annual Land Cost	$69	$69	$69	$69	$69	$69	$69	$69	$69
Gold Annual Capital Cost	$297	$297	$297	$297	$297	$297	$297	$297	$297
Gold Total (Operating, Land & Capital)	646	641	609	662	625	644	604	655	576

Appendix 16: Comparing Costs and Pricing for Parking Space - Light Green Permits



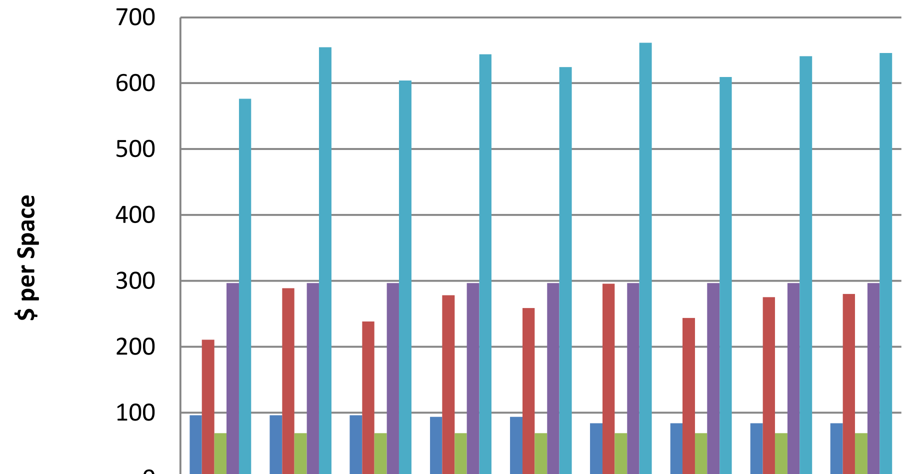
	2010/2011	2009/2010	2008/2009	2007/2008	2006/2007	2005/2006	2004/2005	2003/2004	2002/2003
Light Green Annual Price/Fees	170	170	170	166	166	150	150	150	150
Light Green Annual Operating Cost	$211	$289	$238	$278	$259	$296	$244	$275	$280
Light Green Annual Land Cost	$69	$69	$69	$69	$69	$69	$69	$69	$69
Light Green Annual Capital Cost	$297	$297	$297	$297	$297	$297	$297	$297	$297
Light Green Total (Operating, Land & Capital)	576	655	604	644	625	662	609	641	646

Appendix 17: Comparing Costs and Pricing for Parking Space - Purple Permits



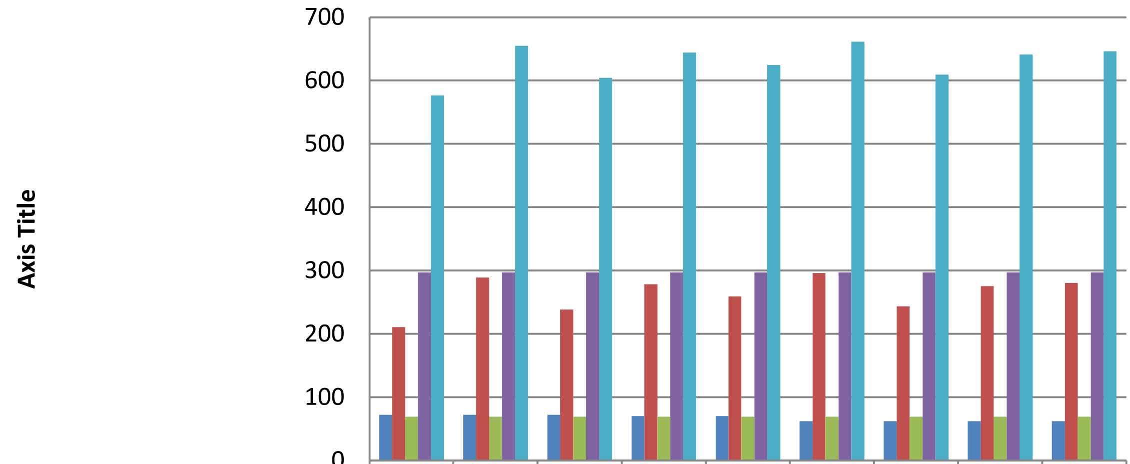
	2010/2011	2009/2010	2008/2009	2007/2008	2006/2007	2005/2006	2004/2005	2003/2004	2002/2003
Purple Annual Price/Fees	134	134	134	130	130	116	116	116	116
Purple Annual Operating Cost	$211	$289	$238	$278	$259	$296	$244	$275	$280
Purple Annual Land Cost	$69	$69	$69	$69	$69	$69	$69	$69	$69
Purple Annual Capital Cost	$297	$297	$297	$297	$297	$297	$297	$297	$297
Purple Total (Operating, Land & Capital)	576	655	604	644	625	662	609	641	646

Appendix 18: Comparing Costs and Pricing for Parking Space - Orange Permits



	2010/2011	2009/2010	2008/2009	2007/2008	2006/2007	2005/2006	2004/2005	2003/2004	2002/2003
Orange Annual Price/Fees	96	96	96	94	94	84	84	84	84
Orange Annual Operating Cost	$211	$289	$238	$278	$259	$296	$244	$275	$280
Orange Annual Land Cost	$69	$69	$69	$69	$69	$69	$69	$69	$69
Orange Annual Capital Cost	$297	$297	$297	$297	$297	$297	$297	$297	$297
Orange Total (Operating, Land & Capital)	576	655	604	644	625	662	609	641	646

Appendix 19: Comparing Costs and Pricing for Parking Space - Dark Green Permits

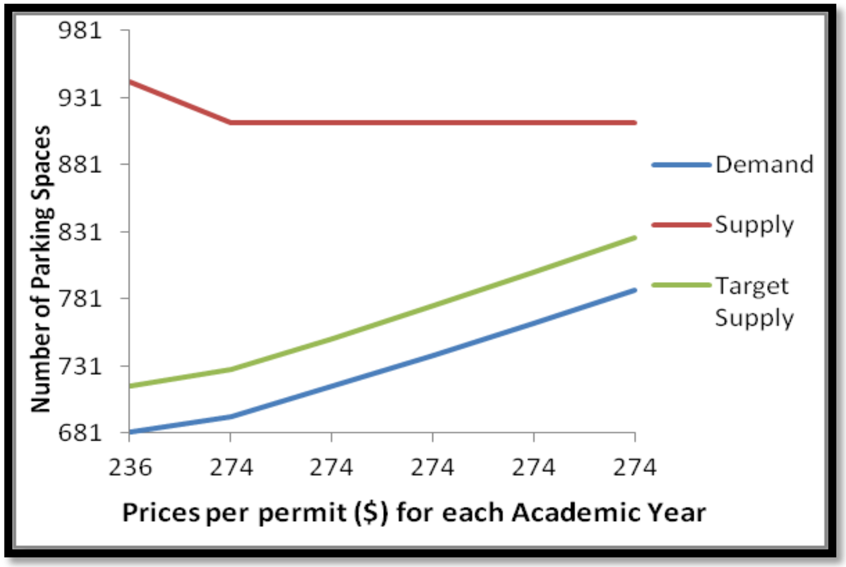


	2010/2011	2009/2010	2008/2009	2007/2008	2006/2007	2005/2006	2004/2005	2003/2004	2002/2003
Dark Green Annual Price/Fees	72	72	72	70	70	62	62	62	62
Dark Green Annual Operating Cost	$211	$289	$238	$278	$259	$296	$244	$275	$280
Dark Green Annual Land Cost	$69	$69	$69	$69	$69	$69	$69	$69	$69
Dark Green Annual Capital Cost	$297	$297	$297	$297	$297	$297	$297	$297	$297
Dark Green Total (Operating, Land & Capital)	576	655	604	644	625	662	609	641	646

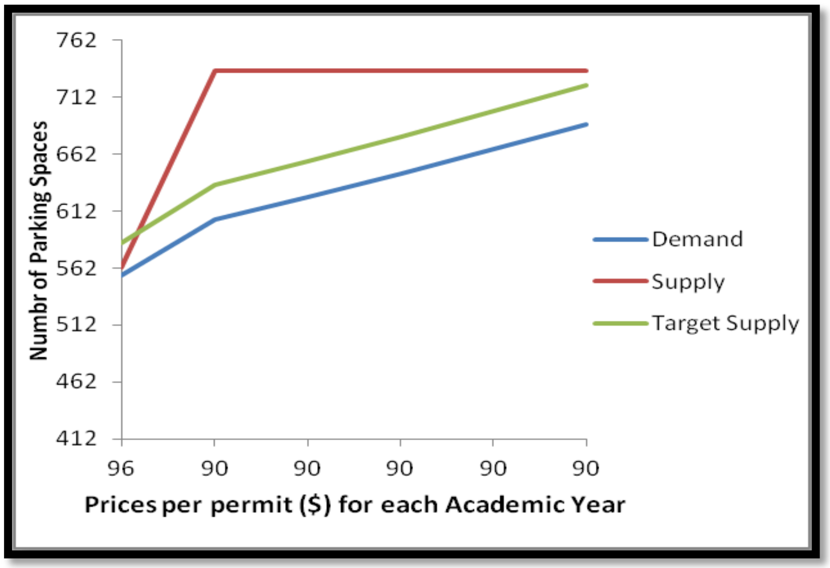
Appendix 20: Parking Cost of Demand and Supply

Academic Year	Annual Operating Cost			Annual Capital Cost			Total Annual Cost		
	Cost of Supply	Cost Of Demand	Deficit/ Surplus	Cost of Supply	Cost of Demand	Deficit/ Surplus	Cost of Supply	Cost of Demand	Deficit/ Surplus
2010/2011	$916,716	$860,086	-$56,630	$1,591,490	$1,493,176	($98,314)	$2,508,206	$2,353,262	-$154,944
2009/2010	$1,235,934	$1,158,495	-$77,438	$1,563,698	$1,465,723	($97,975)	$2,799,632	$2,624,219	-$175,413
2008/2009	$1,019,032	$926,224	-$92,808	$1,563,698	$1,421,285	($142,413)	$2,582,729	$2,347,508	-$235,221
2007/2008	$1,189,778	$1,072,547	-$117,231	$1,563,698	$1,409,623	($154,074)	$2,753,476	$2,482,170	-$271,306
2006/2007	$1,108,876	$955,230	-$153,647	$1,565,526	$1,348,606	($216,921)	$2,674,403	$2,303,835	-$370,567
2005/2006	$1,272,914	$1,110,931	-$161,982	$1,573,206	$1,373,010	($200,195)	$2,846,119	$2,483,942	-$362,178
2004/2005	$1,049,052	$914,882	-$134,170	$1,574,668	$1,373,274	($201,394)	$2,623,720	$2,288,157	-$335,564
2003/2004	$1,228,455	$1,037,182	-$191,273	$1,631,351	$1,377,346	($254,005)	$2,859,806	$2,414,527	-$445,279
2002/2003	$1,218,382	$1,035,756	-$182,626	$1,589,296	$1,351,074	($238,223)	$2,807,678	$2,386,830	-$420,848

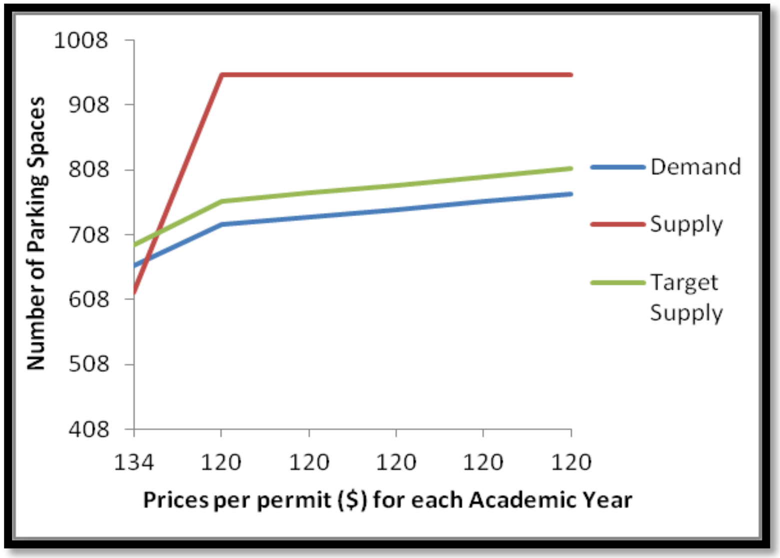
Appendix 21 : Demand and Supply (Gold, Sim Run 1)



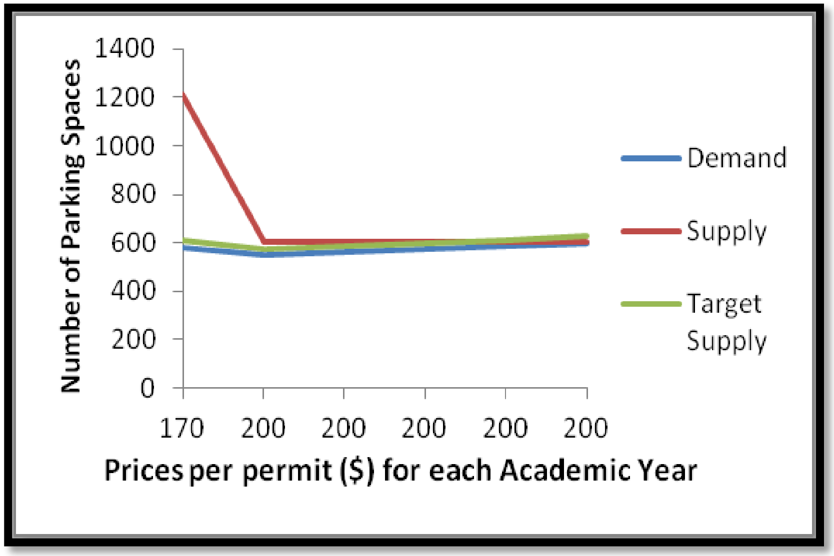
Appendix 22: Demand and Supply (Orange, Sim Run 1)



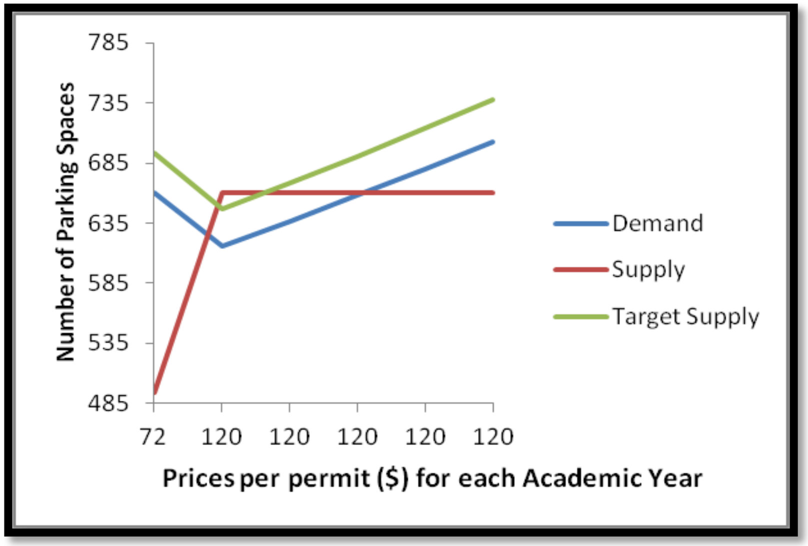
Appendix 23: Demand and Supply (Purple, Sim Run 1)



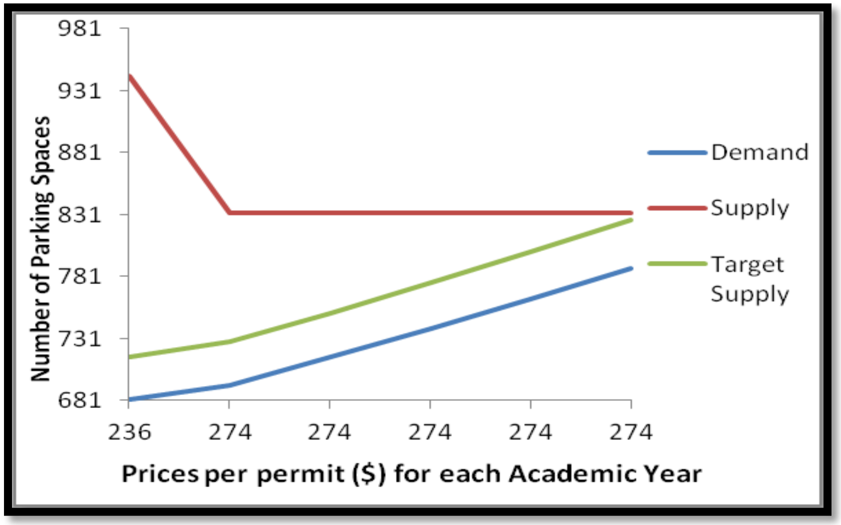
Appendix 24: Demand and Supply (Light Green, Sim Run 1)



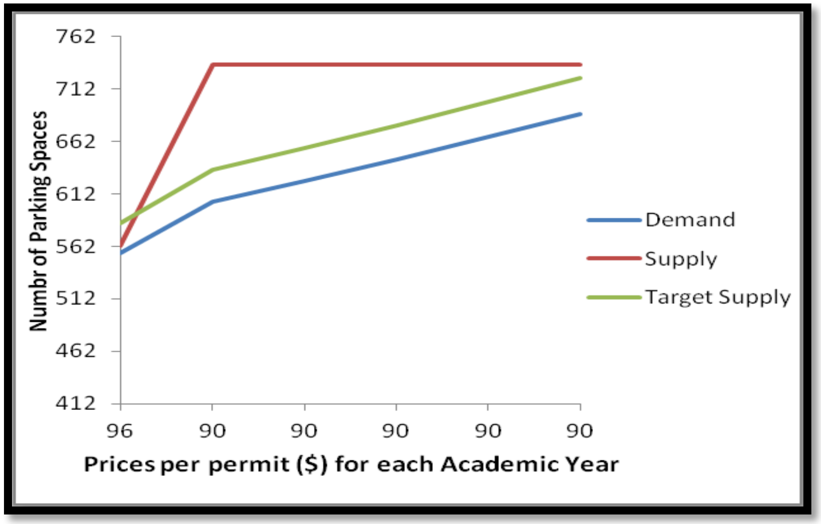
Appendix 25: Demand and Supply (Dark Green, Sim Run 1)



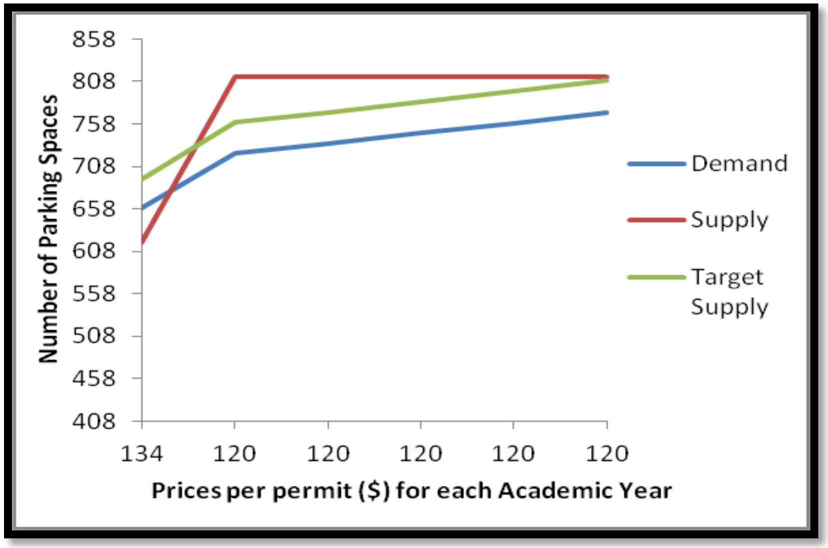
Appendix 26: Demand and Supply (Gold, Sim Run 2)



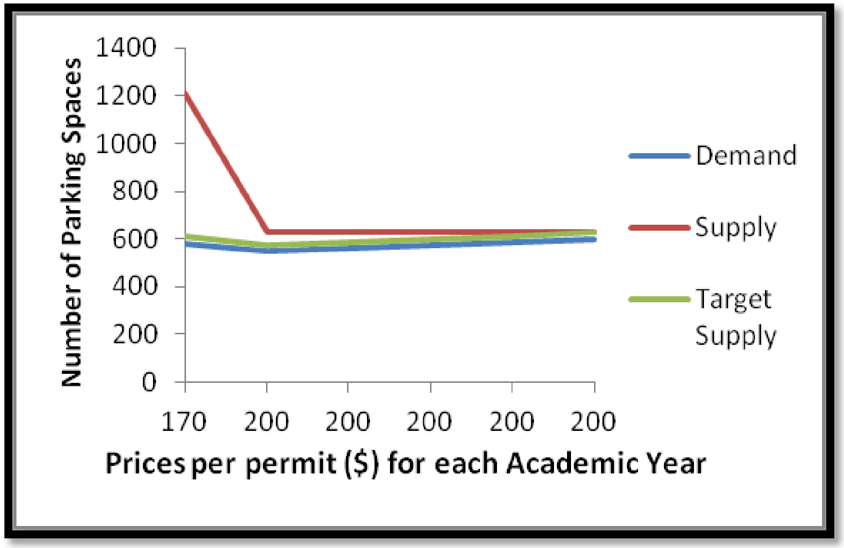
Appendix 27: Demand and Supply (Orange, Sim Run 2)



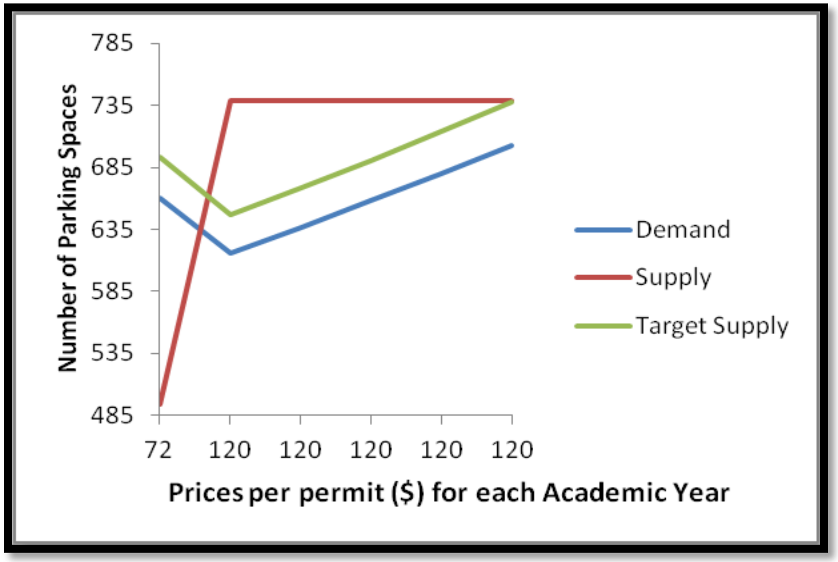
Appendix 28: Demand and Supply (Purple, Sim Run 2)



Appendix 29: Demand and Supply (Light Green, Sim Run 2)



Appendix 30: Demand and Supply (Dark Green, Sim Run 2)



Appendix 31: Formulae Used in Study

- $DR_{rs} = dR_{rs} \times P_{rs}$ .... Equation 1
- $dR_{rs} = RS_p / N_{rs}$ .... Equation 2
- $P_{rs} = PH_{rs} / RS_p$ .... Equation 3
- $DR_{rs} = (RS_p / N_{rs}) * (PH_{rs} / RS_p)$ .... Equation 4
- $DR_{rs} = N_{rs} / PH_{rs}$ .... Equation 4a

where;

DR_{rs} = Demand ratio for resident students

dR_{rs} = driving ratio of resident students

P_{rs} = presence ratio of resident students

RS_p = No. of resident students who purchase permits

N_{rs} = Total No. of resident students

PH_{rs} = No. of resident students present at peak hour/period

RS_p = No. of resident students who purchase permits

$$A = \frac{PV}{\frac{(1+i)^n - 1}{i(1+i)^n}}$$ .... Equation 5

where;

PV = present value or worth
i = interest rate
n = number of years

,

$$levels_t = \int_0^T rates_t dt \quad \text{or} \quad \frac{d}{dt} levels_t = rates_t$$ .... Equation 6

- $NP = Rp * TS$ .... Equation 7
- $NP_p = RP_p * NP$ .... Equation 8

where;

NP = Number of permit users

NP_p = Number of permit users present at peak period

Rp = Ratio of permit users

RP_p = Ratio of permit users present at peak period

- Pr = NP_p / NP .... Equation 9
- dR = NP / TPU .... Equation 10
- DR = Pr * dR .... Equation 11
- D = DR * TDp .... Equation 12

where;

Pr = Presence ratio

dR = Driving ratio

DR = Demand Ratio

D = Demand or the Demand Additions annually.

TU = Total Number of permitted users (This can be the total number of resident students or the total number of non-resident/commuter students plus faculty/staff).

TDp = Total Demand/Peak Use for the previous year

- NN = Rn * TDp .... Equation 13
- DC = $\int_a^b TDp + (D - NN)$ .... Equation 14

where;

NN = Non-parking users Or Demand Subtractions annually

Rn = Ratio of non-parking users

DC = Current Demand

- Effect Price Demand

  =EXP(-Demand Elasticity*LN(Price/Reference Price)) ...... Equation 15
- Effect Price Supply

  =EXP(-Supply Elasticity*LN(Price/Reference Price)) .... Equation 16

- tD = DC * EPD .... Equation 17
- tS = (DC * EPS) * OPS .... Equation 18
- ENPp = tD .... Equation 19
- ENN = NN + (DC - tD) .... Equation 20

Where

tD = Target Demand

EPD = Effect Price Demand

tS = Target Supply

EPS = Effect Price Supply

OPS = Optimum Supply

ENPp = Expected Number of Permit Purchases

ENN = Expected Non-parking Users