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Development of a GIS-based framework for evaluating space and parking utilization

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DEVELOPMENT OF A GIS-BASED FRAMEWORK FOR EVALUATING SPACE AND PARKING UTILIZATION

by

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ABSTRACT

Development of A GIS Based Framework for Evaluating Space and Parking Utilization

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Large organizations such as corporations and universities typically occupy many buildings. A typical university space includes classrooms, laboratories, offices, and parking. The cost of adding additional space is significant. Therefore, effective management and utilization of the space is critical, especially to organizations that are growing. Growth may be measured in terms of the number of employees or students. As the number of employees and students increase, the number of trips to the campus also increase. This poses a growing pressure on the parking supply at the campus.

The main objective of this thesis is to develop a framework for evaluating space utilization. Geographic information system (GIS) software is used as a tool to perform spatial analysis for utilizing the available space and to represent the measures graphically and more effectively. The development of the framework includes six major components: 1) Collect existing space inventory, 2) Develop a means to quantify the demand, supply and utilization of space, 3) Obtain utilization measures of all spaces, 4) Develop tools to

visualize the utilization measures using GIS, 5) Develop a methodology to evaluate accessibility measures and perform analyses, and 6) Develop appropriate interfaces for users to perform queries, analyses and summarize results. The system is expected to assist administrators in better utilizing available space and scheduling classes based on utilization measures and accessibility of parking lots to the classrooms. The University of Nevada, Las Vegas (UNLV) campus is considered as a case study for developing the above framework, and to evaluate its implementation.

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CHAPTER 1

INTRODUCTION

Management of space, i.e., balancing demand and supply, is generally a major concern in large organizations. An increase in growth combined with inefficient planning and demand management can lead to ineffective utilization of available space. The economic losses involved with the inefficient use of existing space are extremely large. Many organizations are addressing the need for better utilization of space using a variety of techniques such as planning and demand management measures, as well as by the provision of more space.

Space requirements vary with the type of organization. In general, organizations include industry, business, governmental organizations, universities and others. Space uses generally includes buildings, parking, open space for pedestrian movement, and traffic circulation. In case of universities, space use includes classrooms, laboratories, libraries, parking, pedestrians, and offices. In this thesis, the University of Nevada, Las Vegas (UNLV) is used as a case study to address the issue of space and parking utilization.

1.1 Motivation

UNLV was officially founded in 1957. It now offers approximately 140 graduate, undergraduate, and doctoral degrees in a variety of fields. The college campus is situated on approximately 335 acres in the Las Vegas metropolitan area. Included within the main campus are 76 buildings and 32 parking lots.

UNLV has grown significantly over the past decade. The UNLV fact-book from Planning, Assessment, Institutional Research (PAIR) indicates that between 1988 and 1998 the student enrollment headcount has grown from 14,825 to 21,312 students, an increase of about 44 % (www.unlv.edu/PAIR/Factbook/index.html). As a percentage of headcount, the number of Full Time Equivalent (FTE) students has increased from 64.9% to 71.9% over the same period. For the year 1998, there were a total of 676 full time instructional faculty and 388 part time faculty. Instructional faculty are those whose major regular assignment is instruction. In 1998, there were 32 parking lots on the campus with a total of 11,203 parking spaces. These include student, faculty/staff, metered, visitor, handicapped and general parking spaces. It is estimated that the number of students will increase to 32,902 by the year 2005, along with an increase of 1,000 parking spaces.

The campus is located in an urbanized area. The main mode of transportation to and from the campus is motorized passenger vehicles, followed by the local bus system. According to the physical master plan statement from the UNLV factbook, the goals of the University include the following:

1) To allow orderly growth to a maximum enrollment on the Las Vegas campus of approximately 35,000 full time students.

2) To use the present land that comprises the campus intensively, with additional land being acquired if necessary, for expansion that cannot now be foreseen. Planning, Assessment, Institutional Research (PAIR).

In order to satisfy the above two goals it is critical to evaluate the utilization of existing space and parking lots. A space utilization study is necessary to assist management in developing a working knowledge of available space and the kinds of use. Proper utilization of space is essential, as it is costly to build, costly to maintain and repair, and requires time to increase the supply of space. Thus, any addition to a physical plant should be done only after careful study of the existing space.

1.2 Objective and Scope of Study

An increase in demand accompanied by a less than proportional increase in supply could lead to space management problems. There are two ways by which a university can accommodate an increase in demand. One is to enlarge the physical plant, i.e., build new facilities. The other is to make more effective use of existing facilities to the extent possible, i.e., demand management. The provision of additional space is an expensive and time-consuming alternative. The effective utilization of existing space can often be implemented relatively easily and without much capital investment in a short time frame. The strategies focus on balancing the need for demand and the existing supply, so that the space is utilized more efficiently. The problem of space itself has its roots in accessibility. Since demand for space directly depends on accessibility in terms of location. UNLV is taken as a case study because of its growth over the past decade and projections for the same into the future. The main objectives of this thesis are as follows:

1) Collect existing inventory space (supply), 2) Develop a means to quantify the demand, supply and utilization of space, 3) Obtain utilization measures of all spaces, 4) Develop tools to visualize the utilization measures using Geographic Information System (GIS), 5) Develop a methodology to evaluate accessibility from parking lots to the buildings and to perform analyses using the accessibility measures developed, and 6) Develop appropriate interfaces for users to perform queries, analyses and summarize results. The system is expected to assist administrators in better utilizing the available space and to schedule classes based on utilization measures and accessibility of parking lots to the classrooms. The development of the above framework and evaluation of its implementation is illustrated using data from UNLV.

1.3 Computer Modeling

Software programs can be used to facilitate analyses, develop effective user interfaces and display results. The spatial distribution of space on an organization's campus and the large quantity of data related to such space, make the utilization of computerized tools appropriate for various analyses. Further, the powerful capabilities of Geographic Information Systems (GIS) programs to work with spatially distributed information, make GIS programs effective and efficient for spatial analyses. GIS programs used in the modeling and analyses are discussed next.

Geographic Information Systems

A GIS is an organized collection of computer hardware, software, geographic data, and personnel data designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Environmental Systems Research Institute 1993a). A GIS is not simply a computer system for making maps, it is an analytical tool. The major advantage of a GIS is that it allows the identification of display of spatial relationships between map features. A typical GIS includes database systems, which provide the means of storing a wide range of information and updating them without the need to rewrite programs. In general, a GIS can be described as a graphical representation tool with the ability to perform analysis and store large amounts of data spatially. In this thesis, a GIS was used to create a coverage (spatial representation), to obtain the accessibility indices of the parking lots (analysis), and to represent results of analyses graphically (pictorial representation and data storage),

ARC/INFO is an automated set of GIS software (ESRI 1993a). The chief modules of the program that are relevant to this thesis include ARC, ARCEDIT, ARCPLOT, INFO, and TABLE. Each module has its own functions. In ARC/INFO, ARC handles the spatial referencing of the features, while the INFO handles the feature description of the database and spatial features of all the attributes. Geographic data can be represented using one of three different types of features: points, arcs, and polygons. They are defined as follows:

Point: A point is a single x, y coordinate that represents a geographic feature too small to be displayed as a line or area. For example a label is represented as a point feature in a coverage.

Arc: Arc is a string of x, y coordinate pairs that begin at one location and end at another. Arc is used to represent linear feature and a polygon boundary in a coverage.

Polygon: A polygon is an areal feature defined by the arcs that make up its boundary. Every polygon contains one label point inside its boundary.

INFO or other tables contain rows and columns. Descriptive attributes about some object, such as a geographic feature are contained in each row. The same column in each row represents the same attribute. The three major topological concepts of ARC/INFO are connectivity, contiguity, and area definition. (ESRI 1993a). They are defined as follows.

Connectivity: Arcs connect at a common node.

Contiguity: Arcs have direction such as right and left polygons of each arc.

Area: A homogeneous area bounded by one or more arc features.

These features help in building coverage. A coverage stores map features as primary and secondary features. A coverage usually represents a single theme, or layer, such as buildings, parking lots, streets, or bus stops.

ArcView is a powerful, easy-to-use tool that brings geographic information to the desktop. ArcView gives the user, the power to visualize, explore, query, and analyze data spatially. A key feature of ArcView is that it is easy to load tabular data, such as dBASE files. In this thesis ArcView is used to display ARC/INFO data, color code maps, layout and print them.

In this thesis coverage of buildings and parking lots were built to identify the locations of parking lots and buildings spatially. These coverages are used to represent the utilization measures of the buildings and parking lots by type and day of the week in color-coded maps, to determine the area and number of parking spaces in a parking lot, and to obtain accessibility indices from the parking lots to the buildings.

ARC/INFO also has a provision to program using ARC Macro Language (AML). It is a high level, algorithmic language that provides programming capabilities. Features include the ability to create onscreen menus from text files, to use and assign variables. In this thesis, AML is used to convert polygon coverages into point coverages. It is also used to automate the process of obtaining accessibility indices.

1.4 Outline of Thesis

A review of the literature on space utilization studies at various universities and large organizations, and accessibility indices is presented in chapter 2. Chapter 3 presents the methodology involved in developing the framework and various utilization measures and their formulation. Chapter 4 deals with the implementation of the framework developed for accessibility indices. In chapter 5, a case study and analysis of the results obtained from case study are documented. A summary of the efforts and outcomes of this thesis and recommendations for further work are provided in chapter 6.

CHAPTER 2

LITERATURE REVIEW

Russell and Doi (1957) gave the fundamental formulation of space at colleges and universities. A space utilization study can be broadly defined as an organized procedure to obtain measures of the use of space designed for a particular kind of activity. This thesis considers three different types of 'space' on a university campus - classrooms, laboratories, and parking. The objectives of this chapter are to review the literature for related efforts. Specifically they include the following.

1) To identify various methodologies adopted by organizations in dealing the problem of building and parking space utilization.
2) To identify various ways in which accessibility measures have been formulated and the methods by which these measures have been used in a GIS environment.

2.1 Space Utilization Studies

The following section includes summaries of efforts of the various universities which conducted space utilization studies and methodologies adopted to represent utilization measures.

University of Minnesota:

The University of Minnesota currently has 80,000 students, faculty and staff. Facility assets are valued over $3 billion and 24 million square feet of space which include 1,000 buildings on 5 major campuses and more than 20 research sites and experimental stations. An existing inventory has led the university to reevaluate the use of their existing space, resulting in the implementation of a new space management system (SPACE) in 1997 (Gondeck-Becker 1999). The SPACE system was designed to integrate facilities information from other enterprise databases for decision support by academic and administrative groups.

The centerpiece of the SPACE system is the Navigator, a graphical navigation and reporting component built on ArcView GIS technology. The main Database management System component is Oracle. It provides detailed information on the occupancy, size, use, accessibility and other characteristics of space. AutoCAD was used for the maintenance of floor plans and campus maps.

Arizona State University:

Arizona's public universities conducted a space utilization study in 1996. Results of the study are tabulated in Table 2.1.

Table 2.1. Analysis of Classroom Space at Arizona's Universities

Base on current Arizona guidelines	ASU	NAU	UA
Existing classroom space (sqft)	352,813	161,827	267,919
Estimated space needs (sqft)	378,638	166,274	324,091
Shortage of space (sqft)	25,825	4,447	56,172

ASU: Arizona State University

NAU: Northern Arizona University

UA: University of Arizona

As the statistics in Table 2.1 show, Arizona's public universities need to use their existing classroom space more effectively to better address their space shortage. Hence Arizona State University developed the prototype of its new Space Management GIS. The prototype was built using ArcView as a GIS platform with links to the departments space inventory database developed in Microsoft access (Arizona Board of Regents, 1997). A future expansion using ArcView Internet Map server is envisioned to provide details to users. Extensive studies were conducted for classroom and laboratory space utilization. The (Arizona Board of Regents, 1997) guidelines minimum criterion requires that classrooms be utilized a minimum of 30 hours per weekday time and 60% of the seats need to be occupied. The proposed guidelines include definitions for four types of classroom space: classrooms (traditional), lecture rooms (traditional theater type fixed seating), seminar (movable seats), and computer instructional (computer terminals at each seat). Several recommendations were given to improve classroom utilization. They are as follows:

1) Universities need to take steps to ensure technology-equipped classrooms are more intensively used.
2) The universities should schedule more classes through central offices and expand their use of computer scheduling programs that improves efficiency and effectiveness.
3) Universities should fully implement best practices in space management.

North Carolina State University:

The North Carolina State University encompasses a total of 1,020 acres and a total of 180 buildings. Student population has increased from 18,103 (1981) to 21,894 (1991). The growth of the university has inevitably led to space management problems. The greater population of students, faculty and staff has taxed the parking and transportation system at North Carolina State University (NCSU). Hence NCSU has conducted space management studies to address space related problems due to increases in student growth. Utilization studies were conducted for instructional space for the years 1981 and 1991 (NCSU). Utilization measures of classrooms and laboratories include average weekly room use in hours, percentage of station occupation per hour of assigned use, total number of rooms, stations, area and scope for future work to improve usage of technology rooms, maintenance, parking and safety are addressed.

University of Oregon:

The University of Oregon is encompassed by 3,270 on-campus parking spaces, a student enrollment of 17,010 and faculty staff employment of 3,400. With approximately 3,270 on-campus spaces, a student enrollment of 17,010 and faculty/staff employment of 3,400 the university has one of the lowest ratios, at 6.2 population/space, compared to other universities. Hence the University of Oregon conducted utilization studies of parking lots at their campus (BRW Inc, 1996). Extensive studies were conducted to analyze the parking structure of the campus. The analysis included three parts.

1) A review of existing and projected conditions.
2) A survey of transportation strategies at other universities.
3) Analysis of potential strategies for the University of Oregon. The analysis mainly deals with daytime transportation needs.

Observations at the University of Oregon show that 39 percent drive to campus, 29.4 percent walk, 15.6 percent bike, 13.6 percent public transit, and 2 percent carpool. The existing parking supply is effectively (fully) utilized for faculty/student parking at the University of Oregon. Field observations were conducted to obtain utilization measures. Results indicate utilization of 83% to 78% for faculty/staff and 97% to 99% for student during the daytime peak. As an extension to the above data, travel patterns of students and faculty was conducted. Projected conditions for year 2000 was also estimated using data from the year 1995.

2.2 Overview of Accessibility

Accessibility measures have been developed for many purposes such as land use planning, urban infrastructure planning, and transportation network analysis. The main objective of the literature review is to study the methodologies adopted specifically for land accessibility. The research methodologies in this chapter are cited with the early methods to some of the more recently used methods. Land accessibility is usually related to its proximity to employment, business, schools, entertainment, and other urban functions.

Methods adopted by different organizations:

ESRI (ARC INFO help manual) gives a definition of accessibility. It is defined as an aggregate measure of how accessible a location is to other locations. Accessibility can be calculated for location of shops, employment, population, and comparison between different shops by using accessibility as a measure. Accessibility indices can also be computed by specifying a search radius. For example, if one lived within one mile of a supermarket, the person has a higher accessibility to the supermarket services than if the person lived two miles away from the supermarket. The amount of supply of goods at a location can also influence the effect it has on the accessibility. The accessibility indices or values can also be computed by specifying a search radius to limit how far to search around each location.

Ingram (1971) presented a conceptual and operational definition for accessibility in terms of relative and integral accessibilities. These were further developed in terms of distance measures such as straight line (or Euclidean distance) and rectangular (or Manhattan) distance. It was recommended that a measure based on normal, or Gaussian curve was the most suitable form for determining integral accessibility. Relative accessibility was used to measure the degree to which two places on the same surface are connected.

Robinson (1977) defined different qualities of accessibility. One measure defined accessibility for a place; second measure defined the relative accessibility of several places, with reference to a single simple network. A third viewpoint suggested is that of accessibility to a network. The fourth group of accessibility measures identified the relative accessibility of several locations within a defined area. Robinson defined different methods of measurements of accessibility. Some of them are linear distances, e.g. (Kilometers or miles or feet), time, or cost. The focus of the study was on the structure within which movement of people takes place, i.e., the networks and modes of transport, and the influence of these on the spatial quality of locations.

Eck (1990) used pressure maps as a methodology to find accessibility indices to evaluate the use of parking lots. Pressure maps were first used in combination with GIS to evaluate the use of parking spaces. The idea was to count how many people want to park their car and how many parking spaces are available within a reasonable walking distance. The resulting quotient was used to identify areas with shortage of parking spaces.

Puebla and Aguayo (1995) reported on the design, implementation, and results of a trans-european scale transportation accessibility model. The implementation of the model used indicators of 'absolute accessibility'. An accessibility indicator was established to undertake the study. The indicator formulation was based on calculating the average impedance of each node in relation to the different economic centers through the network (using the minimum cost path), taking as a weight factor the gross Domestic Product (GDP).

$$A_i = \frac{\sum_{j=1}^{n} (I_{ij} \times GDP_j)}{\sum_{j=1}^{n} GDP_j} \qquad \text{......(2.1)}$$

where, A_i = Accessibility of the node i

I_{ij} = Real impedance between nodes i and j

GDP_j = GDP of the destination economic activity center j.

Holm and Stavanger (1997) studied urban planning concepts such as mobility of a company and about the accessibility to one zone from all other zones within a defined planning area, and how the accessibility changes with an alteration in land use and public transport services. The authors developed a PC-based method of analysis and visualization of mobility and accessibility to be used in urban planning. Accessibility was calculated using travel time, including walking time and waiting time, weighted by population data.

Sathisan and Srinivasan (1998) presented a methodology to identify accessibility from the perspective of transportation network. An automated tool was developed in order to apply the methodology across various networks within a metropolitan area and to compare networks in different metropolitan areas. The trip generation stage along with a GIS based approach was used to develop a program that evaluates accessibility measures and present them in graphical manner.

Pulugurtha, Nambisan, and Srinivasan (1999) presented a working definition for transit market potential based on accessibility in terms of walking distance and walking time. A measure was constructed to evaluate the transit market potential for a transit system. The measure was represented by an index value based on demographic criteria such as employment, household size, vehicle ownership, etc. ARC/INFO, a GIS program, was employed to assess and analyze spatial data. The methods used to define the accessible zone include the following: Arc length method, Buffer method, and Hull polygon method.

Eck and de Jong (1999) presented different methods to construct accessibility surface as a tool for facility location planning with special reference to shops. The authors focussed on the aspect of accessibility to estimate demand as the most important factor in decision making process. The two methods applied were proximity count method and gravity surface- pressure map method. The main difference between the two methods is that the proximity method assumes deterministic, strictly bounded market areas and the other methods (gravity surface and pressure maps) assume non-deterministic fuzzy market areas.

Proximity Method: An assumption was made that people will go to a store nearby irrespective of supply. Based on the population data and distances to existing shops, number of people for whom a shop at that location would be nearer is calculated.

Gravity surface approach: In general gravity surface model postulates that the amount of interaction between an origin and destination increases proportionally with the sizes of the origin and destination but decreases with some function of the distance between them. They used three formulae to estimate the turnover for a site in location i.

$$A_j = \frac{1}{(\sum_i W_i \times f(c_{ij}))}$$

$$T_{ij} = A_j \times W_i \times D_j \times f(c_{ij}) \quad \text{......(2.2)}$$

$$O_i = \sum_j T_{ij}$$

where, A_j = Balancing factor for demand location j

W_i = Attraction value for site i

$f(c_{ij})$ = Function of distance between i and j

c_{ij} = Distance between demand location j and site i

D_j = Demand at location j

T_{ij} = Estimated trips between demand location j and site i

O_i = Estimated turnover in site i

Pressure map: The calculation of pressure map is a two step procedure. In the first step, for each demand location the number of shops within a defined distance is calculated. The demand is than translated into a demand share by dividing the amount of demand at that location by the number of shops within reach.

Jiang, Claramunt, and Batty (1999) defined accessibility as an indices, which measure the nearness or propinquity of one place *i* to other places *j*. The authors defined accessibility as geographic accessibility and geometric accessibility, developed measures for measurement of geometric accessibility, which is applicable to fine scale urban structure at the street building level of representation. ArcView, GIS a software extension within the desktop, was used to implement the measure, allowing the user to generate accessibility measures through new computational measures.

In generalized terms the geographic measure is defined as:

$$A_i = \sum_j f\left(W_j, d_{ij}\right) \qquad \text{......(2.3)}$$

where, A_i = Accessibility of a fixed location i

W_j = Index of Attraction of j

d_{ij} = Measure of the impedance of moving from i and j

Equation 2.3 defines geographic accessibility as it is not used to measure the accessibility of lines or routes. But when the relative location and nearness of locations from one to another is more structured and needs an analogous concept to geographic accessibility, they defined it as geometric accessibility. The physical distance is more important and attraction of a point cannot be defined. Setting the attraction $W_j = 1$ for all j, equation 2.3 becomes:

$$A_i = \sum_j A_{ij} = \sum_j f(d_{ij}) \qquad \text{......(2.4)}$$

where, A_{ij} = Accessibility of j with respect to i

d_{ij} = Measure of impedance between i and j.

Arwyn (1999) addressed defining and developing a regional index of "transportation richness" which takes into account the proximity and diversity of various transportation methods within the European union. A series of buffers around access nodes to a particular transport network, which identified those areas within a specified distance, was developed. These were used to develop a transportation index. Here accessibility was scored according to the distance time. Areas closer to an access point have a higher score than those farther away.

Parentela and Nambisan (2000) developed a GIS based tool for emergency preparedness. Emergency preparedness is the availability of information such as location of emergency response providers, spatial and temporal distribution of various sub groups (hospitals, children etc), and those related to the Environment. In essence, they quantified accessibility using proximity of emergency response centers to areas by representing the proximal areas using Thiessen polygons. Several GIS based methodologies that can support such efforts were presented in the paper. They include address matching or geocoding, routing and allocation, Thiessen polygon, buffering, dynamic segmentation, and overlay functions.

2.3 Summary

The literature review shows that several attempts have been made to study the utilization of space, develop accessibility indices and provide measures to address the space utilization problem. Determining the utilization measures of classroom and laboratories is a traditional method of solving utilization problems at university campuses. Some universities have included parking utilization measures to quantify parking problems. Most of the models (except for University of Minnesota) did not address accessibility issues to quantify building occupancy and parking supply. Moreover, very few of the models had any associated graphical interface for easy visual representation of utilization measures of buildings and parking lots or for visualizing accessibility. It can, therefore, be seen that there is a need for quantifying building occupancy and parking lots by constructing accessibility indices and representing them graphically. Additional required aspects that warrant further study include the following.

1. The model should include four important components such as utilization of buildings, parking lots, accessibility between buildings and parking lots, and querying capabilities needed to complete a space utilization study.

2. It should be broad-based so that it can be used to help in future planning and scheduling.

3. It must be easy to generate accessibility indices and present the results graphically.

4. The model should provide a user friendly interface for the users, i.e., a front-end application such as a Visual Basic tool needs to be developed.

CHAPTER 3

DEVELOPMENT OF UTILIZATION MEASURES

The literature review revealed various methods by which space utilization problems were solved by different organizations. The focus of this chapter is on the development of a methodology that addresses the concerns cited in chapter 1.

3.1 Definitions

Russell and Doi (1957) defined a few critical terms commonly used in space utilization studies at universities. They are presented next.

Units:

1. Class: An academic unit of one or more students formally organized for instruction in a specific course under supervision of an instructor.
2. Class size: The number of students enrolled in a class.

3. Station: A student station is a chair, or a seat, or a laboratory desk, or some other facility to accommodate a student.
4. Total class hours: A class hour is a unit of time approximating one hour. Generally a class of 50 minutes of instruction with an allowance of 10 minutes for changing the classes is considered as 1 total class hour.
5. Actual Usage: Actual usage is the total number of students enrolled multiplied by the total class hours in a week.
6. Daytime: Time of day specified as morning 8:00 A.M – 5:00 P.M Monday through Friday is considered as daytime.
7. Evening-time: Time of day specified as 5:00 P.M – 10:00 P.M Monday through Friday is considered as evening time.

3.2 Methods for Defining Utilization Measures

In this thesis, utilization refers to utilization of buildings and parking lots on a university campus. In the following section, a detailed analysis of the development of the utilization measures is discussed. Various methods used to construct the building utilization measures and parking utilization are discussed. This is followed by a discussion of the computer models adopted to develop the utilization measures.

3.3 Building Utilization Measures

Rooms in buildings are of various types: classrooms, laboratories, conference rooms, faculty/staff offices, restrooms, maintenance/equipment rooms, and study lounges etc. The focus of this research is on classrooms and laboratories. Utilization of a classroom or laboratory can be measured based on different criteria. Various factors are applicable in selecting the criteria. They include number of class hours utilized and number of student stations occupied. Student enrollment in classes could vary within a day and between days of the week. Hence, measures also need to be constructed based on day and evening classes. Similarly, student enrollment and number of stations usage varies between classes and laboratories. Therefore, building utilization is measured based on such type of usage. Building utilization is evaluated using the following three measures:

1. Room utilization in hours.
2. Percentage of room period utilization.
3. Percentage of student station utilization.

These are discussed next.

3.3.1 Room Utilization in Hours

Room utilization is measured in terms of total credit hours. Utilization measures are developed using the available classroom and laboratory inventory. Measures may be calculated for classrooms, laboratories, and both of them together for each individual building or for multiple buildings. Typically, one class period of 50 minutes duration per week at a university or college is considered as 1 credit hour. Thus, a 3 credit hour class is one which meets for a total of 2 hours and 30 minutes per week. Room utilization is measured based on the minimum criteria specified in the National Center for Education

Statistics, (NCES 1992). A classroom utilized for 43.3 hours a week. (that is, 30 hours during daytime and 13.3 hours during evening time) is considered to be utilized 100 percent. Any classroom utilized more than 43.3 hours a week has a usage of more than 100 percent. Utilization measures are constructed for five days a week: Monday through Friday.

Similarly, utilization measures are developed for laboratories based on minimum criteria. The minimum requirement for a laboratory is 29 hours a week, which includes 20 hours of daytime and 9 hours of evening time per week as specified in the (NCES 1992) handbook. A laboratory utilized for 29 hours per week is considered to be utilized 100 percent. Any laboratory utilized more than 29 hours per week has a usage of more than 100 percent.

Room period utilization in hours is measured for classrooms and laboratories individually for day and evening time. For a building, the room period use is calculated as the sum of all total credit hours in all classrooms in the building, divided by the total number of classrooms utilized. It is mathematically represented as shown in equations 3.1 to 3.6:

$$C_{C,D} = \frac{\sum_{i=1}^{n} DCH_i}{n} \qquad \text{....(3.1)}$$

$$C_{C,E} = \frac{\sum_{i=1}^{n} ECH_i}{n} \qquad \text{....(3.2)}$$

$$C_{L,D} = \frac{\sum_{j=1}^{m} DLH_j}{m} \qquad \text{.....(3.3)}$$

$$C_{L,E} = \frac{\sum_{j=1}^{m} ELH_j}{m} \qquad \text{....(3.4)}$$

$$B_D = \frac{\sum_{i=1}^{n} DCH_i + \sum_{j=1}^{m} DLH_j}{n+m} \qquad \text{....(3.5)}$$

$$B_E = \frac{\sum_{i=1}^{n} ECH_i + \sum_{j=1}^{m} ELH_j}{n+m} \qquad \text{....(3.6)}$$

where,

n = Number of scheduled classrooms in a building

m = Number of scheduled laboratories in a building

$C_{C,D}$ = Average classroom utilization in a building during daytime

$C_{C,E}$ = Average classroom utilization in a building during evening time

$C_{L,D}$ = Average laboratory utilization in a building during daytime

$C_{L,E}$ = Average laboratory utilization in a building during evening time

B_D = Average building utilization during daytime

B_E = Average building utilization during evening time

DCH_i = Number of scheduled class hours in classroom i during daytime in a building

DLH_j = Number of scheduled laboratory hours in laboratory j during daytime in a building

ECH_i = Number of scheduled class hours in classroom i during evening time in a building

ELH_j = Number of scheduled laboratory hours in laboratory j during evening time in a building

3.3.2 Percentage of Room Utilization

Typically, utilization measures are represented as percentage utilization. Hence, following equations 3.7, 3.8 and 3.9 present the utilization measures in percentages. Equation 3.7 describes the percentage utilization of a classroom. It is defined as the sum of all the class-hours multiplied by 100 and divided by the product of the maximum number of hours of class utilization expected for each room and total number of rooms. Similarly, Equation 3.8 describes the percentage utilization of a laboratory. This is defined as the sum of all the laboratory-hours multiplied by 100 and divided by the product of the maximum number of hours of laboratory utilization expected for each room and divided by the total number of laboratories. MaxClassutil in equation 3.7 is 43.3 hours and MaxLabutil in equation 3.8 is 29 hours as defined by NCES (1992) handbook Equation 3.9 describes the utilization of a building, which includes all classrooms and laboratories in a building.

$$P_{C,B} = \frac{\sum_{i=1}^{n} CH_i \times 100}{(MaxClassutil \times n)} \quad \ldots\ldots(3.7)$$

$$P_{L,B} = \frac{\sum_{j=1}^{m} LH_j \times 100}{(MaxLabutil \times m)} \quad \ldots\ldots(3.8)$$

$$P_B = \frac{\sum_{i=1}^{n} CH_i + \sum_{j=1}^{m} LH_j}{(MaxClassutil \times n) + (MaxLabutil \times m)} \times 100 \quad \ldots..(3.9)$$

where,

n, and m as defined previously

$P_{C,B}$ = Percentage of classroom utilization in a building

$P_{L,B}$ = Percentage of laboratory utilization in a building

P_B = Percentage utilization of a building

CH_i = Number of scheduled class hours in a classroom i in the building

LH_j = Number of scheduled laboratory hours in a laboratory j in the building

3.3.3 Percentage of Student Station Utilization

The process by which the utilization of student stations in classrooms and laboratories can be calculated is based on the proportion of student stations utilized. The percentages of student station utilization are shown in equations 3.10 to 3.15. The MaxCD, MaxCE in equations 3.10 and 3.11 are the maximum class utilization expected during daytime and evening time. Similarly, MaxLD and MaxLE in equations 3.12 and 3.13 are the maximum laboratory daytime and evening time utilization expected during a week. This is based on minimum criteria specified in NCES handbook, (NCES 1992) i.e., 43.3 hours (MaxCD = 30 hours and MaxCE = 13.3 hours during evening) and 29 hours (MaxLD = 20 hours and MaxLE = 9 hours during evening). Equations 3.10 to 3.13 describe the utilization of student stations based during day and evening hours, and equations 3.14 and 3.15 describe the total student station utilization for a building during day and evening hours.

$$S_{C,D} = \frac{\sum_{i=1}^{n}\sum_{k=1}^{x} SE_{i,k}}{S_i \times MaxCD} \times 100 \qquad \ldots(3.10)$$

$$S_{C,E} = \frac{\sum_{i=1}^{n}\sum_{k=1}^{x} SE_{i,k}}{S_i \times MaxCE} \times 100 \qquad \ldots.(3.11)$$

$$S_{L,D} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{x} SE_{j,k}}{S_j \times MaxLD} \times 100 \quad \text{...(3.12)}$$

$$S_{L,E} = \frac{\sum_{j=1}^{m} \sum_{k=1}^{x} SE_{j,k}}{S_j \times MaxLE} \times 100 \quad \text{...(3.13)}$$

$$S_{B,D} = \frac{\sum_{i=1}^{n} \sum_{k=1}^{x} SE_{i,k} + \sum_{j=1}^{m} \sum_{k=1}^{x} SE_{j,k}}{(S_i \times MaxCD) + (S_j \times MaxLD)} \times 100 \quad \text{...(3.14)}$$

$$S_{B,E} = \frac{\sum_{i=1}^{n} \sum_{k=1}^{x} SE_{i,k} + \sum_{j=1}^{m} \sum_{k=1}^{x} SE_{j,k}}{(S_i \times MaxCE) + (S_j \times MaxDE)} \times 100 \quad \text{...(3.15)}$$

where,

i=1,...n is the number of classrooms

j=1,....m is the number of laboratories

k=1,...x is the number of class periods

MaxCD = 30 hours

MaxCE = 13.3 hours

MaxLD = 20 hours

MaxLE = 9 hours

$S_{C,D}$ = Student station Utilization in a Classroom i in a building during daytime D

$S_{C,E}$ = Student station Utilization in a Classroom i in a building during evening time E

$S_{L,D}$ = Student station Utilization in a Laboratory j in a building during daytime D

$S_{L,E}$ = Student station Utilization in a Laboratory j in a building during evening time E

$S_{B,D}$ = Total student station utilization in a building during daytime

$S_{B,E}$ = Total student station utilization in a building during evening time

S_i = Number of stations in classroom i

S_j = Number of stations in laboratory j

$SE_{i,k}$ = Number of students enrolled during class period k in classroom i

$SE_{j,k}$ = Number of students enrolled during class period k in laboratory j

The above methodology described is implemented to perform the analysis and obtain results.

3.4 Parking Utilization

Parking demand at universities increase because of increases in student enrollment or special events. The main objective of a parking utilization evaluation is to assess the demand for parking compared to the parking supply available. The evaluation is needed to determine characteristics which affect parking demand. These characteristics include the mode of transportation used to travel from and to the university, percentage of students parking on-campus and off-campus, location of parking with respect to first and last activities on the campus. A better understanding of these aspects is necessary to correlate the demand for parking with characteristics of student parking and accessibility of parking lots.

3.4.1 Criteria for Data Collection

Utilization measures for parking lots are measured based on three different criteria. They are:

- Type of usage
- Day of the week
- Time of the day

Type of usage: Out of several parking types six types of parking spaces were examined for the purpose of this study. UNLV needs parking permits for on campus parking except for metered spots. The six types of parking spaces at UNLV are:

- Student: Student parking spaces are for use by the students at the University who require parking permit. A vehicle with a faculty/staff permit may also park in such space.
- Faculty/Staff: Faculty parking spaces are exclusively used by the faculty/staff at the University who require faculty parking permit.
- Handicapped: Handicapped parking spaces are exclusively used by vehicles with a physically disabled permit.
- Visitors: Visitor parking spaces are used by visitors who pay a parking fee at the time of entrance.
- Metered: Metered parking spaces are used by visitors or people who do not have a permit to park in any other parking spot.
- Resident: Resident parking lots are used by students or faculty who live on campus.

Day of the week: At UNLV classes typically are offered on a Monday/Wednesday/Friday schedule or on a Tuesday/Thursday schedule for 3 credit classes. Thus, if a course is offered on Monday the same course also meets on Wednesdays. Similarly if a course is offered on Tuesdays the same course also meets on

Thursdays. Hence, it can be assumed that the student enrollment is almost same on Monday and Wednesday during daytime/evening time. Similarly, it is assumed that enrollment is same on Tuesday and Thursday during daytime/evening time (note that there could be a small difference due to classes which are offered once a week). Thus, only three days of a week are considered for data collection. Data could be collected on Monday or Wednesday, Tuesday or Thursday, and Friday.

Time of day: Student enrollment varies by day of the week and time of the day. Hence different times of the day have to be considered for data collection. Data are collected during different times of the day. These timings are selected based on various criteria and factors. The time of the day is best selected based on the student enrollment figures. For example consider the morning peak, the afternoon peak, and the evening peak based on the maximum enrollment at a particular time. Several different timings are considered: four during the morning peak and two during the evening peak hours on Mondays, three during the morning peak and three during the evening peak hours on Tuesdays, and four during Friday morning peak hours. Note that these timings are established based on student enrollment at UNLV during spring semester in1998.

3.4.2 Data Collection Methodologies

To study the utilization of parking lots two different kinds of methods are developed. They are as follows:

- Field Surveys
- In-class Surveys

3.4.2.1 Field Surveys

The main objective in conducting the field survey is to determine the peak period occupancy of parking lots. The methodology involves data collection, data computation, and analysis. Data collection includes determining the number of parking spaces occupied in each parking lot for each type of usage. Typically, a parking lot is divided into different sub-lots based on type of usage. These as stated previously include student, faculty, handicapped, metered, resident, and visitor. Hence, data collection has to be performed for all different types of sub-lots. A survey sheet was prepared for data collection. The survey sheet includes the name of the observer, date and time of survey conducted. Table 3.1 illustrates the parking survey sheet. Column 1 of Table 3.1 is the parking lot identifier. The number of parking spaces occupied in a parking lot is entered in the other columns based on the type of usage. The time for collecting the data has to be identified based on student enrollment during a day.

Table 3.1. Survey for Parking Lots

Date:		Time:		Name of the observer		
Number of occupied parking spaces						
Lot	Student	Faculty	Metered	Visitors	Handicapped	Resident

A database should be designed and the data collected should be maintained in the database. The design of the database is illustrated in Table 3.2.

Table 3.2. Design of Database for Parking Survey

Field name	Data type	Description
Lot	Text	Parking lot considered for survey
Day of week	Text	Day of the week the survey was conducted
Time	Date/Time	Time of the day the survey was conducted
Type	Text	Type of usage of a parking lot
Number occupied	Number	Number of parking spaces occupied in a lot
Number of spaces	Number	Total number of parking spaces available

The first column in Table 3.2 is the field name. A field name can be 64 characters long including spaces. The field names include lot, day of the week, time, type, number occupied, and number of spaces available. The second column consists of data type. The data type determines the kind of values the users can store in the field. These include data types such as text, number, and date/time formats. Third column consists of description of the field.

Data computation involves calculation of the AM and the PM peak utilization of parking lots by day of the week. The number of parking spaces occupied should be compared with the supply of each parking lot. A parking utilization measure can be represented as percentage utilization as shown in equations 3.16 and 3.17.

$$PU_{ijt} = \frac{PO_{ijt}}{P_{ij}} \times 100 \qquad \ldots(3.16)$$

$$TPU_{jt} = \frac{\sum_{i=1}^{p} PO_{ijt}}{\sum_{i=1}^{p} P_{ij}} \times 100 \qquad \ldots..(3.17)$$

where,

P_{ij} = Total number of parking spaces available in lot j for parking type i

PO_{ijt} = Number of parking spaces of type i occupied in lot j at time t

PU_{ijt} = Parking utilization of type i in parking lot j at time t

TPU_{jt} = Total parking utilization in parking lot j at time t

j = Parking lot

i =1, 2,....p (1= student, 2= faculty, 3= handicapped, 4= visitor, 5= metered, 6= resident)

t = time of the day (here, AM peak and PM peak)

Here, equation 3.16 calculates the percentage utilization of parking lot based on type of usage and time of day. Equation 3.17 calculates the total percentage utilization of parking of all types in a lot j at time t.

3.4.2.2 In-Class Surveys

The main objective of conducting in-class surveys is to obtain the mode of transportation to the university, percentage of students parking on-campus and off-campus, percentage of parking lots used based on building location for the first and the last class for a student. The data collection involves designing a questionnaire and conducting surveys throughout the campus. In-class surveys were conducted in several buildings around the campus. The survey form designed for this purpose is shown in Figure 3.1. The survey forms need to be filled out and completed by students on campus.

The next step is to design the table to enter the data obtained from the survey questionnaire. Table 3.3 illustrates the design of the data entry table. The table includes nine different columns. Column 1 is the name of the building in which the survey is conducted, and the rest of the eight columns are the results obtained from the questionnaire. Columns 2, 3, 4, 5, 8 and 9 are single character fields such as a, b, c, etc. Columns 1, 6 and 7 are three letter characters, i.e., abbreviation of the building. Each row consists of the data collected from each student.

Data computation involves calculating the percentage of students using different modes of transportation, percentage of students parking on-campus and off-campus, and percentage of students using a parking lot. Data computation is done using queries.

Table 3.3. Design of Table for Results From In-class Survey

Date:		Time:		Name of observer				
Building	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8

The flow chart in Figure 3.2 summarizes the procedure involved in the study of utilization of parking lots based on the two methods discussed in the above sections. The first method is conducting field surveys to obtain the percentage utilization of parking lots. The second method is conducting in-class surveys to obtain the mode of transportation and percentage of students parking on-campus. The steps involved in both the methods are data collection, reduce to the required data, data computation and analysis of the results.

Survey for Parking

1) How did you come to UNLV today?
   a) Drove an automobile
   b) As a passenger in an automobile that was parked at UNLV
   c) Dropped off by an automobile
   d) Bus/Transit
   e) Motorcycle/Moped
   f) Bicycle
   g) Walk
   h) Other

2) Was the vehicle parked:
   a) On campus b) Off campus c) Not Applicable

3) Which parking lot did you use? [Identify by letter e.g. 'R'(See the Map)]

4) Why are you using this parking lot?
   a) Closest to your 1st class b) Closest to your last class of the day c) Other

5) In which Building is your 1st class for the day?

6) In which Building is your Last class for the day?

7) At what time did you arrive on-campus?
   a) Before 8 AM b) 8-9 AM c) 9-10 AM
   d) 10-11AM e) 11 AM-Noon f) Noon-1 AM
   g) 1-2 PM h) 2-3 PM i) 3-4 PM
   j) 4-5 PM k) 5-6 PM l) 6-7 PM m) after 7 PM

8) At what time do you plan on leaving the campus today?
   a) Before 8 AM b) 8-9 AM c) 9-10 AM
   d) 10-11AM e) 11 AM-Noon f) Noon-1AM
   g) 1-2 PM h) 2-3 PM i) 3-4 PM
   j) 4-5 PM k) 5-6 PM l) 6-7 PM m) after 7

Figure 3.1. Questionnaire for Parking on UNLV Transportation Access

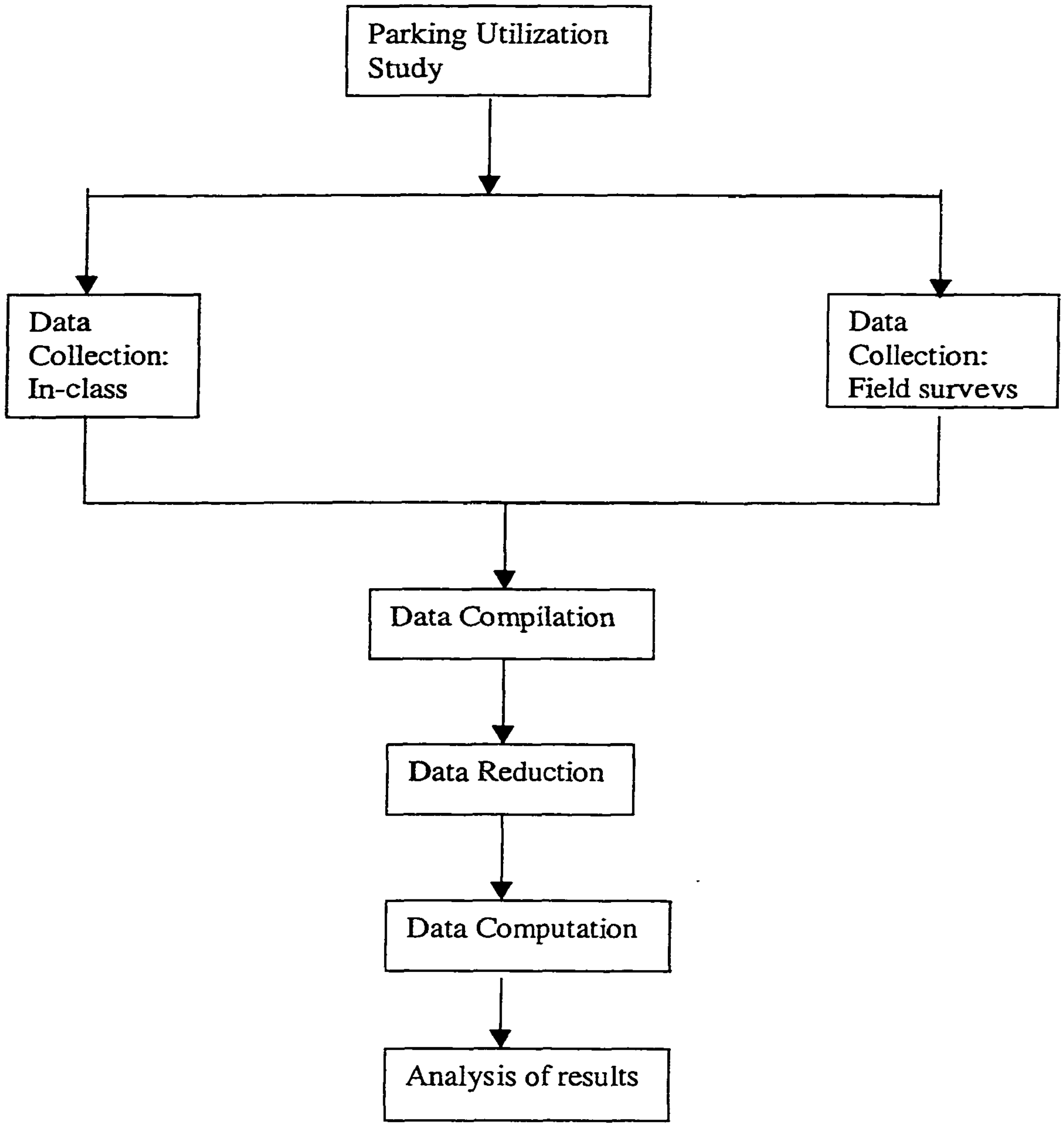


Figure 3.2. Overview of the Parking Utilization Study

3.5 User Interface Development

Development of the utilization measures of campus space is a necessity for space management. It helps in utilizing the space more effectively and efficiently. With an increase in student enrollment, faculty, and staff over time, there will be a need to perform space utilization studies frequently. Hence, a tool needs to be developed to help estimate building utilization measures expeditiously. This tool should be robust and should have capabilities to perform queries and support analysis. The following section describes the data requirements and system architecture for the tool. In this research, Visual Basic is the software used to develop a user interface for such a tool.

3.5.1 Data Requirements

The main objective of developing the tool is to help support the user to perform queries and analysis related to the building utilization measures. The development of the application for this purpose is a two step process. The first step is the design and construction of the database. The second step is the design and development of the front-end application i.e., the user interface. A database with attributes regarding campus space and inventory is required to perform queries and analysis. The attributes include buildings, room number, stations, student enrollment, day of the week, time of the day and total class hours. A description of the design of the database is provided in section 3.5.4. The required data can be obtained from the registrar or the database administrator. Data are designed in a tabular format.

3.5.2 System Architecture

The development of the front-end application or the user interface, the database connection, and the development of queries are based on a system architecture definition. The system architecture definition includes identity and specifications of software, hardware and linkages. Microsoft Access can be used for the database development and Visual Basic programming language (Siler and Jeff, 1998) is used for developing the user interface. After the design of the database, it should be connected to the user interface. Hence the database is connected through an Object Database Connectivity (ODBC) driver. An ODBC user data source stores data on how to connect to the data provider. The designed database is stored in the ODBC driver. The stored database is retrieved using an Active X Data Objects database (ADODB) (Siler and Jeff, 1998). An ADODB is connected to the database using "ADODB.Connection" and data are retrieved using "ADODB.Recordset". The queries are written in the "code window" to retrieve the data from the database. The code window consists of queries, which are written for analysis purposes and executed during run time. Different forms are created for different queries. The queries are developed to retrieve the utilization measures of the buildings. A detailed description of the building utilization measures has been discussed in section 3.3. Equations 3.1 to 3.15 are used to quantify the utilization measures.

The next step is the development of the front-end application or the user interface. User interface consists of a "Form window". The form window needs to be designed for selecting the data or entering the data. A "Form window" is a window in which one designs, using different tools available, an interface for selecting the data from given options or entering the data. Different forms are developed for different types of utilization measures. For example a form is developed for room period utilization, a different form for student station utilization etc. All the different forms are saved in to a single project file. A "project file" is a collection of forms that make a Visual Basic program.

3.5.3 Software Programs Used

The following major software components are used in developing the utilization measures and front-end application.

- Microsoft Access
- Microsoft Visual Basic

Microsoft Access and Visual Basic programs are selected for database maintenance and user interface development. They are selected because they are products from the same corporation and are compatible with each other, and also commonly used in offices as they are not expensive programs. A short description of this software is presented in the next section.

3.5.4 Database Design

Microsoft (MS) Access is a product of Microsoft Office. Data about the buildings, inventory related to all the classrooms, number of students enrolled, room numbers, start time, end time of a class, number of stations, and other attributes related to the classroom, laboratory, office data were obtained from Facilities management Administration (FMA) as a Microsoft Access database. The design of the database constitutes of developing the database table. A "database" is a collection of set of tables. The first step in designing the database is the selection of the required attributes and data entry. A table can be opened in a design view. The design view consists of different field names, their data type and description of the field. They are defined as follows:

Field name: Field name can be 64 character long including spaces and it assigns a name to the field.

Data type: The data type determines the kind of values that users can store in the field. Some of these include text, number, date/time, yes/no etc.

Description: The field description helps describe the field and it is optional.

Table 3.4 shows a design view of a table.

Table 3.4. Design View of a Table

Field Name	Data Type	Description
Building	Text	Three letter prefix of the building
Room no.	Text	Room number of a class
Stations	Number	Number of seats in a class
Start Time	Date/Time	Start time of a class
End Time	Date/Time	End time of a class
Enrolled	Number	Number of students enrolled in a class
Fri	Yes/No	If Yes , class is scheduled on Friday

In this thesis MS Access was used to store data in the form of tables and to query the necessary data. Access database has the capability to link to different tables, join different tables, import and export the data from various tables stored in a different format. In addition, storage of huge amounts of data, querying, writing reports and working with modules can be easily done using MS Access. Hence in this thesis, MS Access was chosen as the database to store data and perform queries. Three different databases were used for the research effort. The first database consists of two tables and a third table from a query. They are as follows: Table 3.4 illustrates the design of the first table

Table 3.4 consists of the following fields.

- Building: A three letter prefix of the building name.
- Room No.: Number of a room in a building.
- Start time: Start time is the time when a scheduled class begins. The format of time is long time. For example 10:30:45 AM.
- End time: End time is the end of the scheduled class. Format of the time is long time.
- Total class time: is the time between the start and the end time of the class represented in minutes.
- Class hours: is the total class time represented in hours.
- Total class hours: is the product of class hours times total times a class meets during a week.
- Enrolled: is the total number of students registered for a class.
- Day of the week: is represented in yes or no. If the class is scheduled on a weekday it says yes else it says no.
- Day/Eve: is represented in a single character letter i.e., 'D' or 'E'. This represents day time or evening time.

Table 2 consists of information about the buildings, room no., type of usage and number of stations in a classroom. Building and room no. are as defined in the Table 3.4.

Type of usage is a three-letter number assigned based on the usage of the room. For example, a classroom is assigned as 110, class laboratory is assigned as 210, office is assigned as 310, 220 is an open laboratory, 250 is a non class laboratory 350 is a conference room, 410 is a reading room, 610 is an assembly, 615 is an assembly service, and 730 is a central storage room. Stations are the number of seats present in a classroom.

The third query table is developed using relational join to obtain all the information in both the tables. A common field from both the tables is joined such that the new table includes all rows where the joined fields from both the tables are equal. Thus the new table consists of all the columns from Table 1 and Table 2.

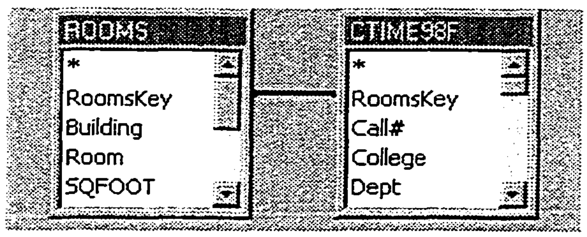


Figure 3.3. Relational Join of Two Tables to Develop a Third Table

The second database consists of six different tables consisting of data about utilization measures of classrooms, laboratories and field surveys conducted for parking lots. Three tables are used to maintain large amounts of data and perform queries to calculate the utilization of parking lots on three different weekdays. Hence, three tables are developed for Monday/Wednesday, Tuesday/Thursday, and Friday. The design of field survey tables for parking lots is described in section 3.4.2.1. Table 3.5 illustrates the table for calculating the parking utilization on a weekday. Three other tables are used to maintain the data obtained from building utilization measures.

Table 3.5. Database Table for Parking Utilization Measures.

Parking lot	Type	AM Peak	AM Demand	PM Peak	PM Demand	Parking supply	% AM Utilization	% PM Utilization

The third database consists of information about the results from in-class surveys. Section 3.4.2.2 discussed the design of the database for in-class surveys. Table 3.3 illustrates the database table for in-class survey results.

3.5.5 Development of User Interfaces

Visual Basic is a programming language developed by Microsoft Corporation. The Visual part refers to the method used to create the graphical user interface (GUI). Pre- built objects are provided to represent the visual part. The Basic part refers to the BASIC (Beginners All-Purpose Symbolic Instructional Code) language (Brain and Jeff, 1998). It is a windows development language that follows an interactive development process. Interactive development allows the user to test the application as it is being developed. Visual Basic has many useful tools that help in developing the front-end application.

The various tools used in developing the user interface are as follows. Combo box, Text box, Command button, MSFlexgrid, Labels, and Option buttons. They are discussed next. A "Combo box" is a tool where the user can choose from the given set of choices. A "Text box" is one where the user can input the data, "Option buttons" are designed as a group and only one option button can be chosen at a time. A "Command button" is used to implement the required action i.e., a command button is used to display the final result. The "MSFlexgrid" has a cell matrix configuration. It is used to display the final result.

The following tools were used in developing the application.

ActiveX Data Objects (ADO)

Active X Data Objects (ADO) is used to perform data access programming tasks for Access databases. There are three distinct ADO object models. One of them is ADO database (ADODB). This object model enables the client applications to access and manipulate data in a database server through an OLEDB provider. "ADODB.Connection" object allows you to establish connection with data sources. Once the connection is established, a ADODB.Recordset is created to retrieve the data.

Option Button:

The option button control is shown in Figure 3.4. The option button control allows the user to select just one option from a given set.

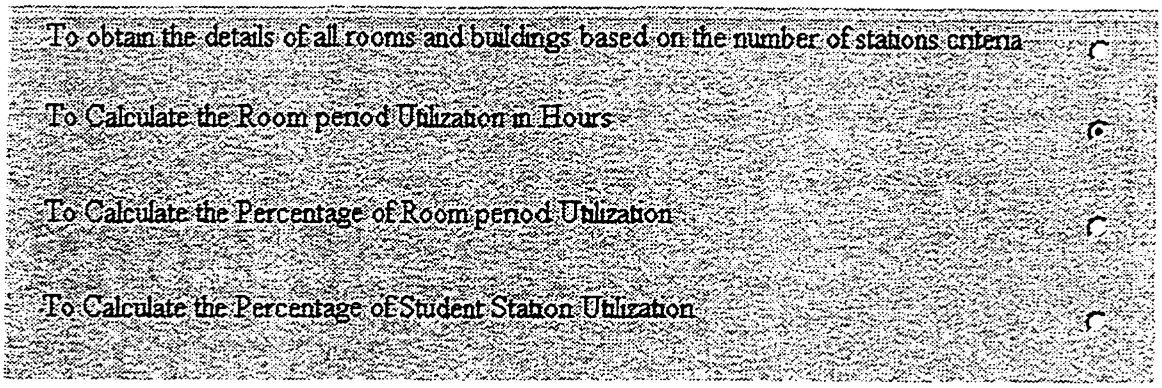


Figure 3.4. Option Button Control

Combo Box:

A combo box control allows the user to select from a set of choices by selecting from the list. Figure 3.5 illustrates a Combo box. There are three different types of combo boxes. Dropdown, simple and dropdown list box are the three different types of combo boxes. The dropdown list combo box is used in this project.

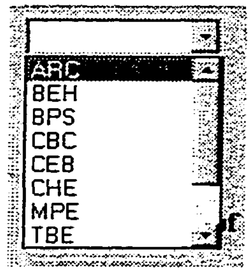


Figure 3.5. Combo Box Control

Text Box:

A text box object displays textual information and allows the user to type in values so those values can be used in the program. Figure 3.6 illustrates a Text box.

Figure 3.6. Text Box Control

Label:

A Label is used by the developer rather than a user. It helps to display text on the form.

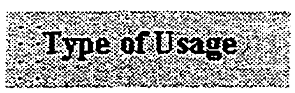


Figure 3.7. Label

Command Button:

Command button is a control when clicked will perform the required action. The command button in this project is connected to the database through the Recordset and ADODB. The command button contains the query and connection to all other components mentioned above. Figure 3.8 illustrates a command button.

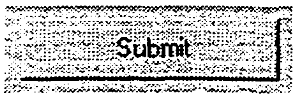


Figure 3.8. Command Button Control

MSFlexgrid:

MSFlexgrid is a spreadsheet like control that allows the display of data in a spreadsheet format linked to the database. It displays the data in a series of rows and columns representing records and fields from a Recordset object. MSFlexgrid is linked to the command button, which is connected to the database through ADODB. Figure 3.9 illustrates a MSFlexgrid.

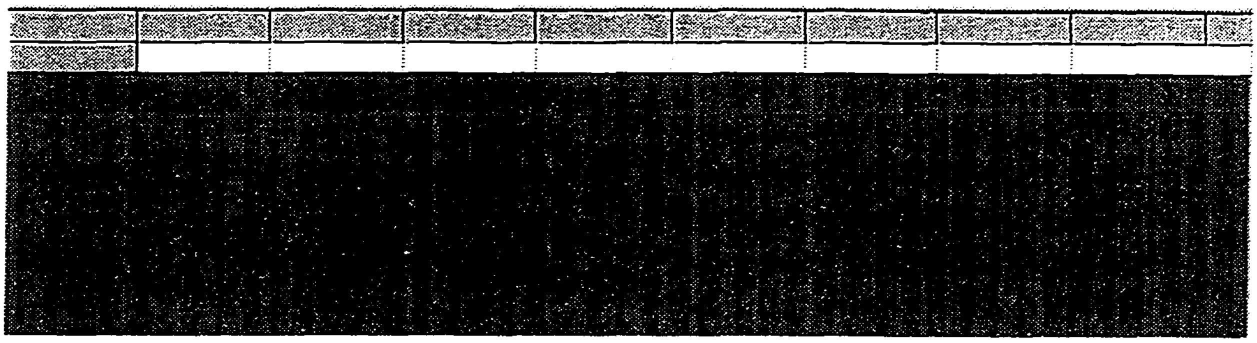


Figure 3.9. MS Flex Grid

Form:

A form is a combination of the tools necessary to accomplish a desired task or activity. Figure 4.0 illustrates the design of a form for querying purposes based on certain criteria. In Figure 4.0 "Building" is a label, the input for building is presented in a Combo box, in addition the day/evening, time of day, type of Usage are presented in Combo Boxes. Room no. is presented in Text box, and submit is the Command button, and the excel spreadsheet is the MS Flexgrid.

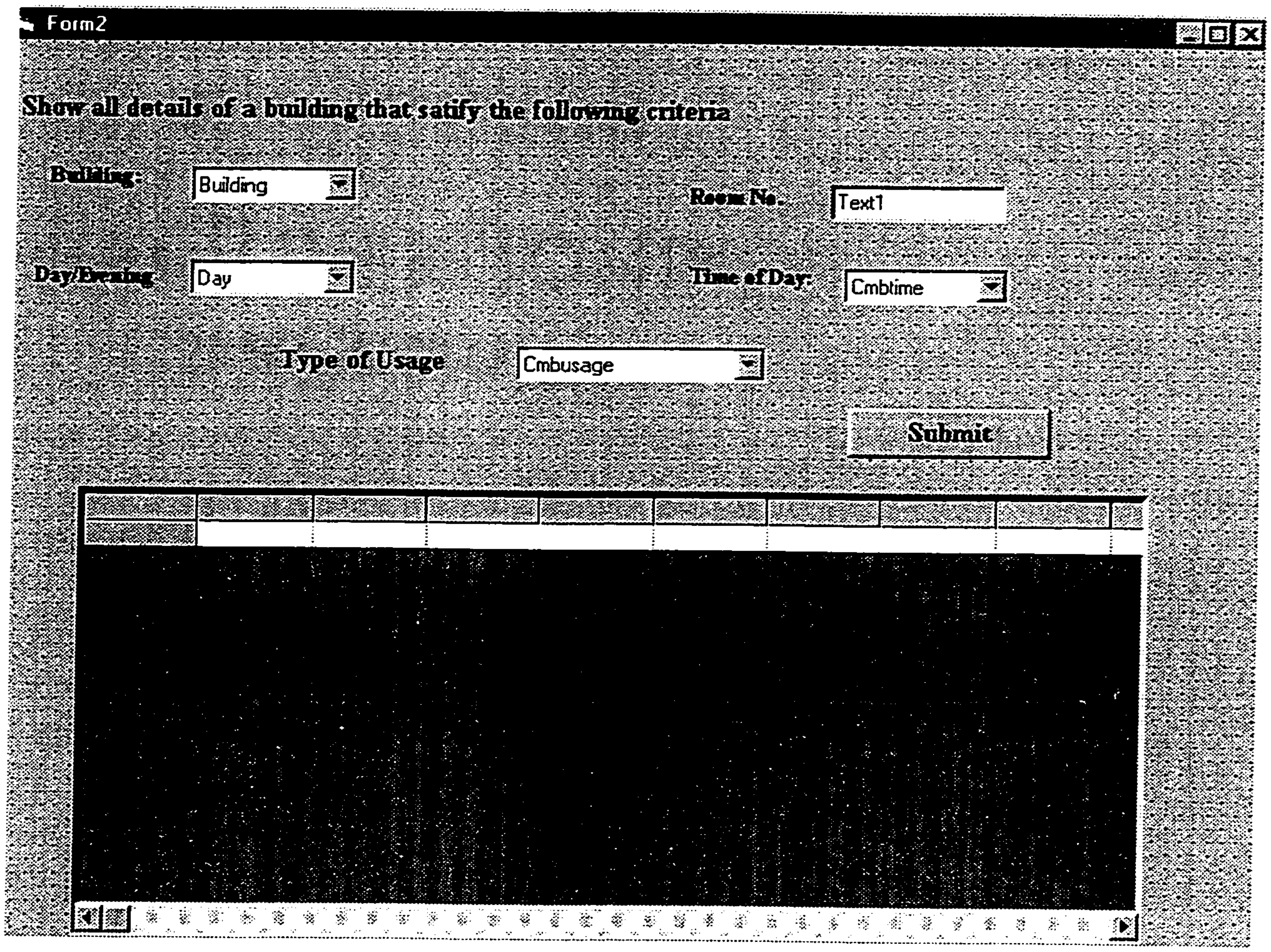


Figure 4.0. A Visual Basic Form

CHAPTER 4

ACCESSIBILITY INDICES

Accessibility, as defined previously in Chapter 2, is proximity to a given location. Generally, students tend to park at a lot which is either accessible to their first class, last class, or direction of arrival to the university. If demand for a parking lot nears or exceeds parking lot capacity, the demand results in congestion. Some parking lots may be utilized to their capacity whereas others may be underutilized. This again depends on accessibility. The accessibility of parking lots to the building influence the utilization of parking lots and other related parking characteristics. Hence, it is extremely critical to identify all the buildings which are within accessible distance to a parking lot and vice versa. This chapter deals with the aspects of accessibility, and methodology involved in developing the accessibility indices.

4.1 Data Requirements

The basic data required for developing accessibility indices are information on the spatial distribution of the individual buildings, individual parking lots and their respective attributes (characteristics). These can be captured in a GIS environment as a building coverage and parking coverage respectively. Polygon coverages are built for buildings and parking lots. Point coverages of buildings and parking lots are required for constructing Thiessen polygons for the purpose of this study. Hence, an AML program is written which converts polygon coverages to point coverages. These coverages are commonly used for all the three different methods of developing accessibility indices.

4.2 Methods for Developing Accessibility Indices

The first step in developing accessibility indices is to identify various methods used to develop accessibility indices. The main objective is to determine indices for all the parking lots and buildings. The different aspects used to develop accessibility indices are:

- Accessibility of parking lots to the buildings, and
- Accessibility of buildings to the parking lots.

The different methods used to develop accessibility indices are the buffer method, the Thiessen polygon method, and a combination of Thiessen and buffer method. The following sections describe each methodology and why the methods are chosen.

4.2.1 Thiessen Polygons

Thiessen and Alter (1911) gave the initial definition of Thiessen polygons which also are called Voronoi diagrams. Thiessen polygons are imaginary polygons which are constructed by connecting a series of point locations with line segments, erecting perpendiculars to those line segments at their midpoints, and then extending those perpendiculars until they intersect. Finally connecting line segments are dissolved; leaving irregularly shaped polygons containing the original points (Okabe et al. 1992). The Thiessen polygon represents the loci of points that are closer to the centroid of the Thiessen polygon than to any other centroid (Gold 1991). Thiessen polygons are defined by drawing a boundary around a set of centroids such that the boundaries enclose all points closest to that centroid. A Thiessen polygon for a center is the loci of points that are closer (in Euclidean space) to the center than to any other center (Parentela and Nambisan 2000). Thiessen polygons can be used to apportion point coverage into regions known as Thiessen or Voronoi polygons. Each region contains only one point. Figure 4.1 illustrates the Thiessen polygons for a set of points.

The Thiessen polygon method helps in finding the proximity but does not help in locating accessible distance say a fixed distance (1000 feet or 304.8m). It is helpful in identifying the proximity but a parking lot may not be accessible in terms of distance traveled, even though it falls within the polygon. These are the drawbacks of this method.

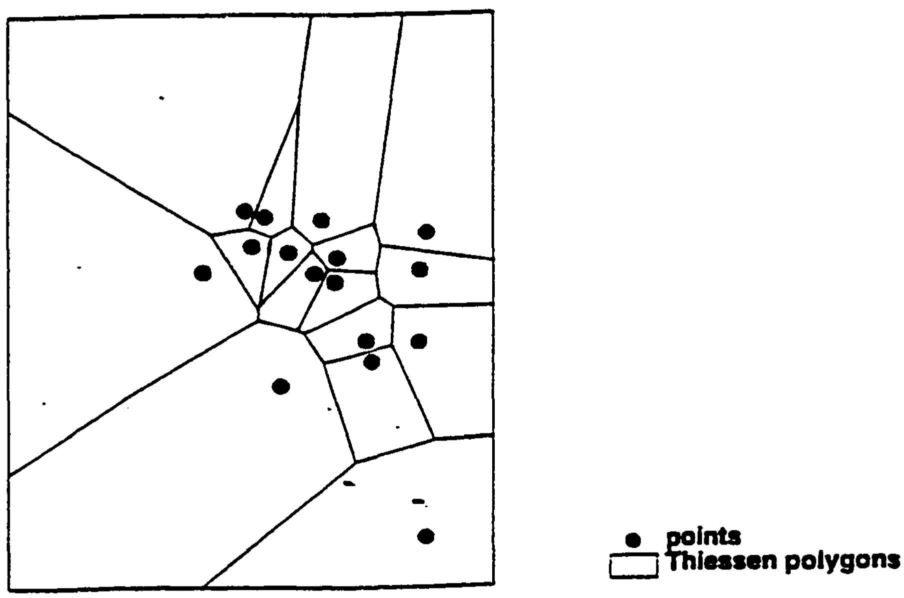


Figure 4.1. Thiessen Polygons for a Set of Points

4.2.2 The Buffer Method

In the buffer method, a buffer zone is drawn around the point of interest to define the accessible region at a fixed distance (say 1,000 feet or 304.8 meters). The buffer zone is considered the most accessible region in reference to a particular location. In other words, it determines the spatial proximity to a location. The distance chosen for buffering maybe on a number of criteria. In this research, it is based on the walking distance. This is estimated considering a maximum walking time of 5 minutes from the parking lot to the building with 4 feet/second walking speed. (Pulugurtha, Nambisan, and Srinivasan, 1999). The authors presented a definition for transit market potential based on accessibility in terms of walking distance and walking time. In this thesis, a similar strategy is used to find out the number of parking spaces near a building or the number of buildings accessible to a parking lot. For example when a buffer is drawn around a parking lot, the number of parking spaces in that buffered zone may be estimated on the proportion of the buffered area within the parking lot to the total area of the parking lot and vice versa for a building. Figure 4.2 illustrates the buffer method. The point represents the building and the polygon represents the parking lot. The shaded region in the parking lot is the buffered zone.

This can be mathematically represented as follows:

$$r_j = \sum_{i=1}^{imax} \left(\frac{a_{ji}}{A_i} \times N_i \right) \qquad \text{......(4.1)}$$

where, i=1, 2,..imax, and imax = Maximum number of parking lots.

r_j = Number of parking spaces in the buffered zone j

a_{ji} = Area of the buffered zone j in polygon i

N_i = Number of parking spaces in polygon i

A_i = Actual area of the polygon i

Equation 4.1 can be used to find the number of parking spaces around a buffered zone based on the defined distance as the most accessible region. In equation 4.1 polygon represents the parking lot and the buffered zone is the area around the building which is buffered. The buffer method can help solve some of the problems associated with the Thiessen polygon method. But with this method some of the problems that arise are that one does not know whether the buffered region falls in the proximal zone. This problem can be solved using the combination of Thiessen and buffer method.

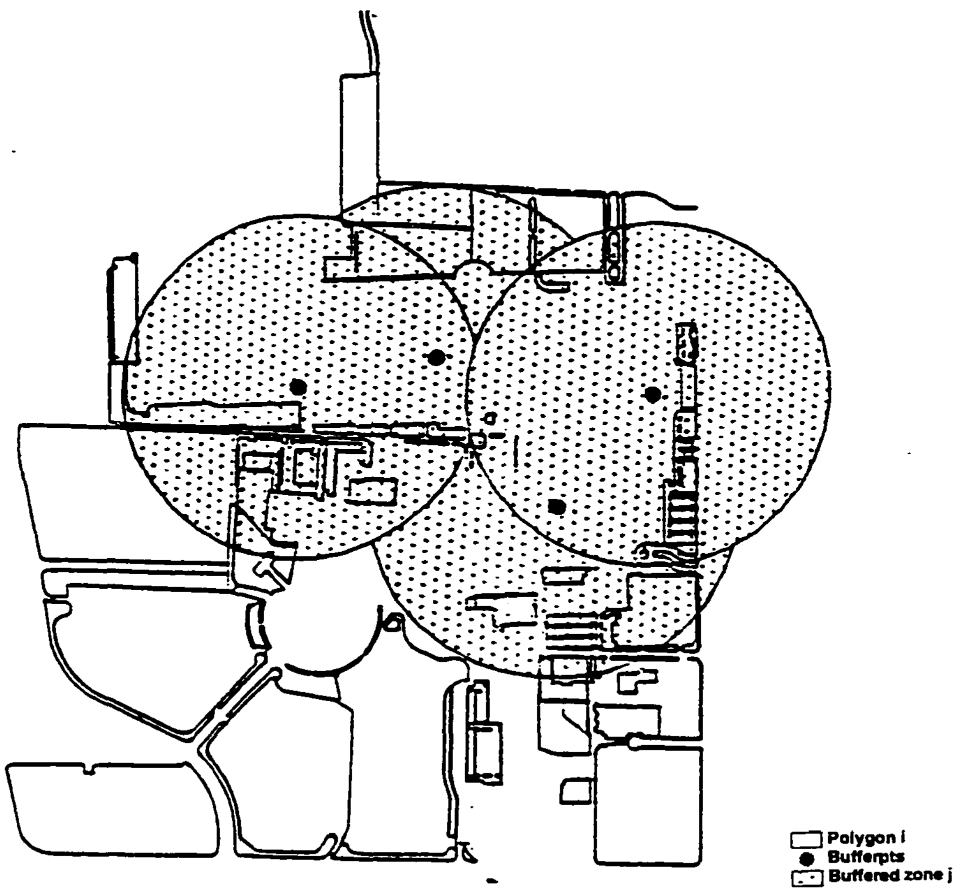


Figure 4.2. Buffer Method

4.2.3 Combination of Thiessen Polygon and Buffer Method

A fixed distance is not assigned when constructing the accessibility indices using the Thiessen polygon method and in the buffer method a proximal zone is not considered while taking fixed distance into consideration. Hence to overcome the problems in the above two cases, a combination of Thiessen and buffer method is used to develop accessibility indices. Thiessen polygons are built around the point coverage of parking lots to find the proximity of the location. Then the point coverage of the parking lot is buffered with a fixed distance to obtain the most accessible region. As a last step, Thiessen polygon coverage and buffer coverage are overlaid to get the most accessible region in that Thiessen polygon or the most accessible distance in the proximity zone. The end result is that a given parking space is in the proximity of a building and is accessible to only one building.

Any of the above approaches essentially involves a spatial overlay, which is easy to visualize in a GIS based environment. Hence the above three methods were chosen to develop accessibility indices as they help in spatial analysis and graphical representation of the results. The first two methods provide significant details about proximity analysis and a fixed accessible distance. But the third method provides accessibility indices at a fixed distance in a proximal zone.

The flow chart in Figure 4.4 summarizes the procedure of the methodology involved in developing accessibility indices. The accessibility indices are structured in terms of two different approaches. The first approach is based on in-class surveys and the second approach is by using GIS software. This involves developing polygon and point coverages of buildings. Three different methods are used as mentioned in the above sections. They are buffer method, Thiessen polygon method and a combination of Thiessen and buffer method.

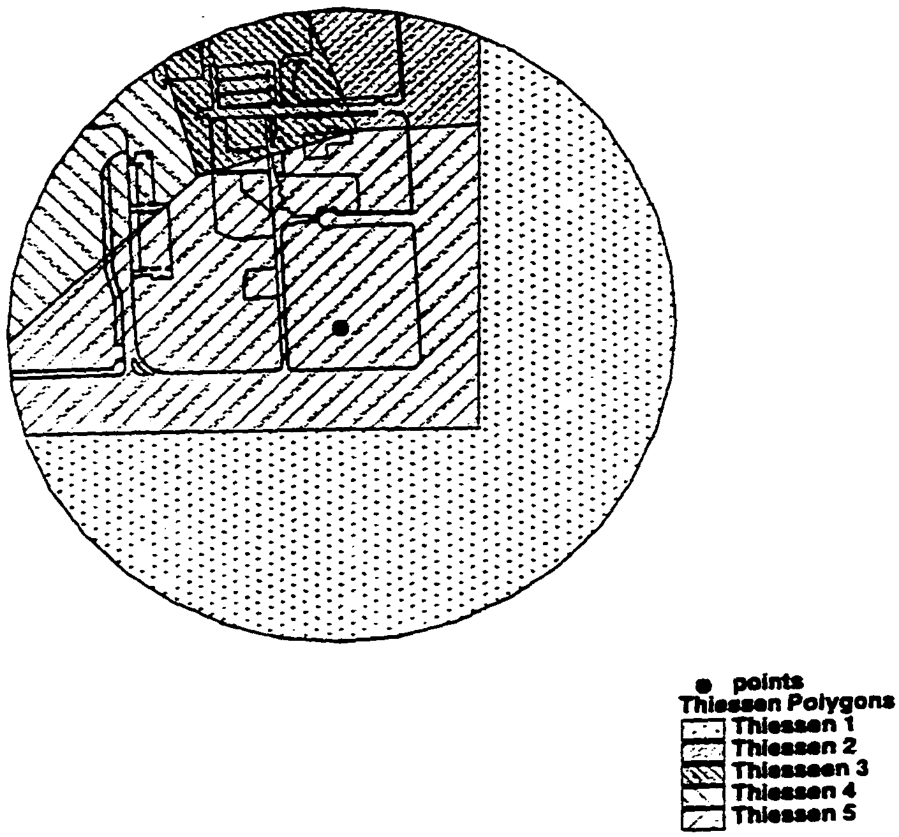


Figure 4.3. Combination of Thiessen polygon and Buffer Method

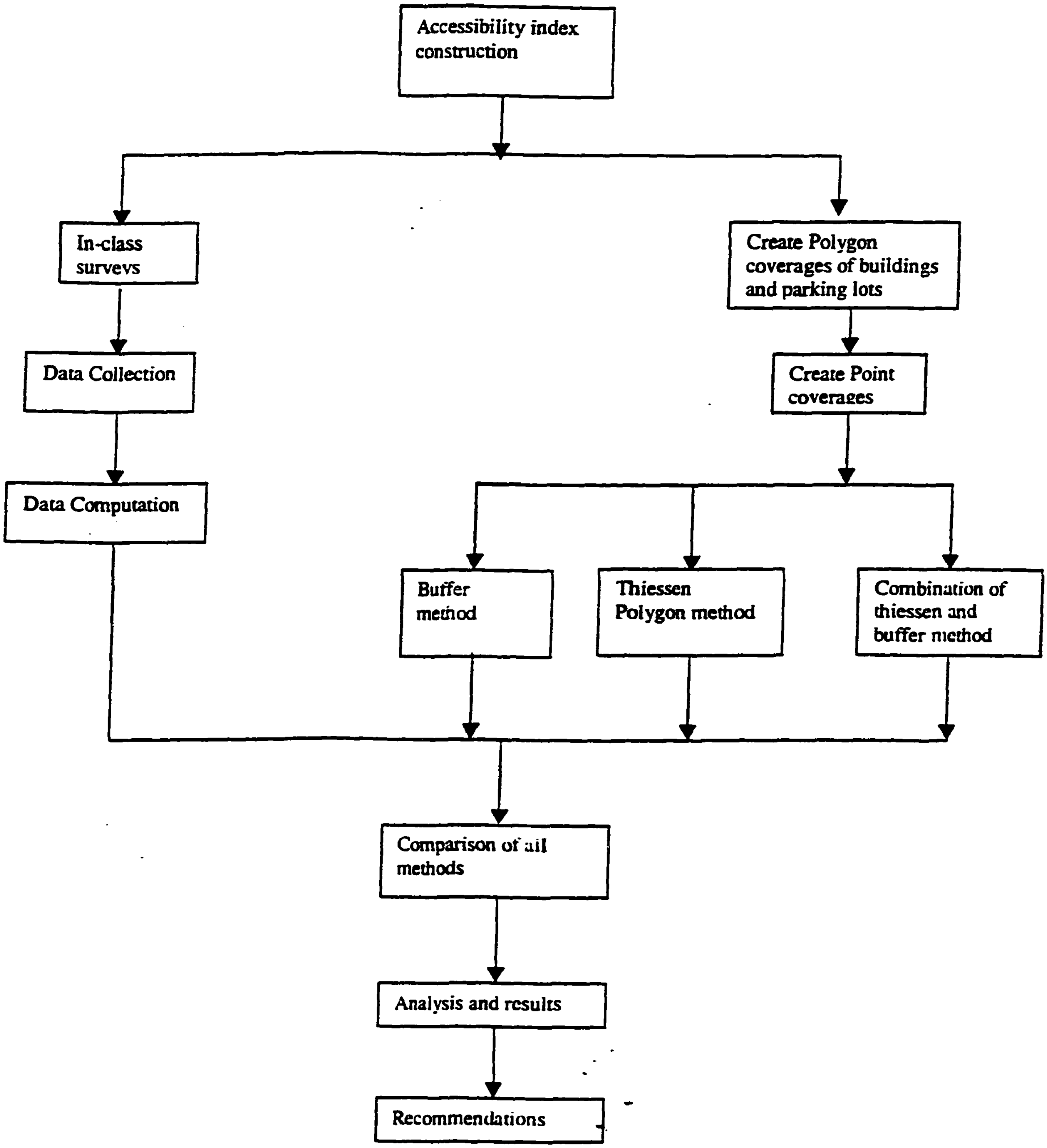


Figure 4.4. Development of Accessibility Indices

4.3 Development of Visualization tools

The building utilization measures and parking utilization measures can be represented in tables, charts or figures. For better understanding of the utilization of the campus and scope of spatial analysis, utilization measures are represented in color-coded maps using ArcView, a GIS program. The following section discusses the data requirements and construction of the visualization tool.

4.3.1 Data requirements

The basic data that are required for developing a visualization tool are the spatial locations of buildings, parking lots and their characteristics and results from the accessibility indices. An AutoCAD drawing of the campus buildings and parking lots was used as a starting point for this purpose. ArcView, a GIS program was chosen as the visualization tool. The second requirement is a database consisting of details about the campus area, which includes area and perimeter of each building and parking lots on campus.

4.3.2 Development of Coverages

The AutoCAD drawings of buildings and parking lots are converted into coverages. It is a two step procedure. The first step involves converting the AutoCAD drawing to a DXF (Drawing Interchange File). The DXF file is then converted into a coverage using Arc/Info command in the GIS environment. Both parking lot and building coverages are created. Buildings and parking lots are developed as polygon coverages. Each polygon constitutes a separate building assigned with certain area and perimeter. Shape files are necessary to develop the color-coded maps. Hence the coverages are converted into shape-files.

The next step is the design of the database. A database is designed to develop the color-coded maps. The database includes attributes of buildings and parking lots. The attributes of building include percentage of room period utilization, percentage of student station utilization for classrooms and laboratories. The attributes of parking lots include percentage utilization of student and faculty parking lots on Mondays, Tuesdays, and Fridays. Based on the variation in percentage utilization, different shading (or coloring), patterns are assigned to each building and parking lot for graphical representation of the information.

CHAPTER 5

IMPLEMENTATION AND RESULTS

This chapter considers the implementation strategy of the methodologies developed in the previous chapters. Data requirements, sources of data, selection of the network, and analyses of the data are described in detail. The application of building utilization measures, parking utilization, user interface and accessibility indices, visualization tools and the results obtained are presented and discussed. This methodology can be applied by any organization provided the specified data are available.

5.1 Case Study: University of Nevada, Las Vegas (UNLV)

The methodology described in chapter 3 and 4 is demonstrated by using the University of Nevada, Las Vegas (UNLV) as a case study.

5.1.1 Data Requirements

The primary requirement for this application developed in this research effort are the availability of data and software for developing the final model. Software includes

MS Access for database maintenance, Visual Basic 6.0 for the user interface, Arc/Info for building the coverages, ArcView for developing visualization tools, and Excel to work on the data. The database consisted of details of the space inventory at the university, student enrollment, and room numbers, time of the day, day of the week, and type of usage. This is provided in MS Access Database developed by the Database administrator at the Facilities Management Administration (FMA) office at UNLV. This database is used to develop the utilization measures and develop the user interface. Different queries are developed from the original database for further studies.

The second requirement is coverages of campus buildings and parking lots. Coverages are built from AutoCad files. These data are useful for developing the visualization tools and to construct accessibility indices. Data are obtained from FMA. Coverages are built separately for buildings and parking lots. The coverages include details about the building area, perimeter, parking lot area, and identification number.

The third requirement is data pertaining to parking lots. It includes an inventory of parking lots i.e., number of parking lots, types of usage, number of parking spaces, and location of parking lots. These data are available from the Public Safety Department. Data such as the number of occupied parking spaces by time of day and day of week, and most accessed parking lots to a building are the required data for the analysis. These are obtained by conducting field surveys and in-class surveys.

The fourth requirement is the availability of Visual Basic software for developing the User interface. The data used for implementing the task is the same database used in calculating the utilization measures provided by the FMA department. Several queries are developed and written in the visual basic code.

5.1.2 Area of Study

The first step is to select the required buildings and parking lots for developing the utilization measures and accessibility indices. There are 75 buildings and 32 parking lots on campus. Buildings are classified into nine different categories based on the purpose or usage:

1. Classroom Buildings
2. Laboratory Buildings
3. Office Buildings
4. Athletic Buildings
5. General purposes
6. Food Court Buildings
7. Health Care Facility Buildings
8. Residential Facility Buildings
9. Special Use Buildings

Similarly parking lots are classified into several categories. They are:

1. Student
2. Faculty/Staff
3. Visitor
4. Metered
5. Handicapped
6. Resident
7. Reserved

8. Daycare

As there are a large number of buildings and parking lots, with the limitations of the scope of study and time available, only 16 buildings and 32 parking lots are taken into consideration for this research effort. Building was selected if it contained classrooms or laboratories. Similarly a parking lot was selected which had any of the different categories such as student, faculty, handicapped, metered, visitors, and resident parking.

5.2 Utilization Measures

Once the data are collected and the area of study selected, the utilization measures are developed for the buildings based on classroom and laboratory category. The measures are developed based on day and evening usage and three different measures are developed as discussed in chapter 3. They are room period utilization in hours by day/evening, room period utilization in percentage, and percentage of student station utilization based on day/evening. Equations 3.1 to 3.15 are applied to construct the utilization measures.

Room Utilization in Hours

The data collected are from the spring semester of 1998. A list of buildings and the three-letter code to represent each building are shown in Appendix A. Table 5.1 and Figures 5.1, and 5.2 show the results of the building utilization measures by type of usage and day/evening usage for 16 different buildings. As shown in the table, three buildings have classrooms that are used for more than 30 hours per week during daytime. They are ARC, FDH, and HFA. Thus, these are used for more than 100 percent of the values identified in NCES handbook. The least used classrooms during the daytime are in BHS and LFG. The room period utilization during daytime on an average is 23 hours and evening time is 10.86 hours for a classroom. Evening utilization of the classrooms is low in many buildings such as BHS, BPB, LFG, CHE, and HFA. Hence, classes can be scheduled in these buildings during evening time for better utilization of the building space.

Similarly, many laboratories were not utilized to the minimum requirements of 20 hours and 9 hours during day and evening respectivley. The average utilization of laboratories is 17.75 hours and 6.49 hours respectively. Hence, the buildings, which are under-utilized during the daytime are ARC, BHS, CEB, FDH, and TBE. The buildings which are under-utilized during evening time are BHS, CHE, GRA, TBE, and WHI. This is because the laboratories are used for other academic and research purposes, those which are not included in the Registrar's master schedule.

Room Utilization in Percentage

Table 5.2 and Figure 5.3 show the results of utilization measures in percentages for all the 16 buildings based on type of usage. BHS is the least utilized, the percentage of utilization being 33 percent. The laboratories that are least utilized are in BHS, CEB, and TBE buildings. Here, total indicates the average weighted utilization of buildings and laboratories in the building. Thus, from Figure 5.3 it can be observed that BHS building is the least utilized both in classrooms and laboratories.

Student Station Utilization in Percentage

The student station utilization index represents the utilization of the stations (seats) that are utilized in a classroom or laboratory. Table 5.3 and Figures 5.4, and 5.5 show the results of student station utilization based on type of usage: day, and evening. The following results are obtained using equations 3.10 to 3.15. The weighted total utilization of student stations for ARC, LFG, CEB, and TBE indicate that they are being under-utilized (both classrooms and laboratories). The utilization of classrooms is better than the utilization of student stations. Hence the stations need to be utilized more efficiently. Utilization of student stations depends on student enrollment for a class and the number of available stations in the allotted classroom for the class. For better utilization classrooms should be allotted based on the student enrollment or the expected student enrollment. However, when the actual enrollment in a class falls short of the projected enrollment, a number of stations in the room assigned to that class go unutilized. This leads to a reduction in the value of the student station utilization index.

Table 5.1. Room Period Utilization in Hours

Building	No. of scheduled clasrooms	No. of Scheduled labs	Classroom Day (Hours)	Classroom Evening (Hours)	Laboratory Day (Hours)	Laboratory Evening (Hours)	Weighted total Day (Hours)	Weighted total Evening (Hours)
ARC	2	5	31.6	14.1	3.1	8.2	11.3	9.9
BEH	29	4	27.3	14.5	17.5	8.1	26.1	13.8
BHS	14	3	10.1	3.9	1.1	3.0	8.5	3.7
BPB	3	9	22.3	4.0	10.2	5.5	13.2	5.1
CBC	55	1	25.0	11.3	16.8	0.0	24.8	11.1
CEB	19	1	17.1	23.9	6.0	6.0	16.6	23.0
CHE	2	5	19.7	5.2	18.4	3.8	18.7	4.2
FDH	10	3	33.3	15.6	8.2	9.0	27.5	14.1
GRA	4	3	15.3	10.7	28.6	2.4	21.0	7.1
HFA	9	10	33.2	4.8	40.0	11.9	36.8	8.5
LFG	3	1	10.6	4.7	40.8	20.4	18.2	8.6
MPE	3	1	19.1	10.0	28.2	6.0	21.4	9.0
TBE	9	9	28.1	13.9	9.4	1.5	18.8	7.7
TEC	1	0	24.0	12.0			24.0	12.0
WHI	1	8	29.0	13.8	20.3	5.1	21.3	6.1
WRI	16	0	22.1	11.4			22.1	11.4
Average	11.25	3.9	23.6	12.3	17.8	6.2	22.1	13.9

Table 5.2. Room Period Utilization in Percentage

Building	No. of scheduled classrooms	No. of scheduled Labs	Classroom (percent)	Laboratory (percent)	Weighted Total (percent)
ARC	2	5	106.0	39.0	64.0
BEH	29	4	97.0	88.0	96.6
BHS	14	3	33.0	14.0	30.3
BPB	3	9	61.0	54.0	56.4
CBC	55	1	84.0	58.0	84.1
CEB	19	1	95.0	41.0	93.6
CHE	2	5	58.0	76.0	69.5
FDH	10	3	114.0	59.0	104.4
GRA	4	3	60.0	107.0	76.0
HFA	9	10	89.0	179.0	127.2
LFG	3	1	36.0	211.0	67.7
MPE	3	1	68.0	118.0	76.8
TBE	9	9	98.0	38.0	73.6
TEC	1	0	84.0		83.7
WHI	1	8	100.0	88.0	89.5
WRI	16	0	78.0		77.8
Average	11.3	3.9	83.4	82.8	83.3

Table 5.3. Student Station Utilization in Percentage

Building	Classroom Day (percent)	Classroom Evening (percent)	Laboratory Day (percent)	Laboratory Evening (percent)	Weighted Total Day (percent)	Weighted Total Evening (percent)
ARC	30.0	36.0	12.0	38.0	26.0	37.0
BEH	66.0	56.0	68.0	66.0	66.0	57.0
BHS	62.0	15.0	4.0	25.0	53.0	16.0
BPB	60.0	11.0	36.0	53.0	52.0	25.0
CBC	45.0	36.0	24.0		45.0	
CEB	35.0	116.0	16.0	58.0	35.0	115.0
CHE	36.0	20.0	69.0	28.0	51.0	24.0
FDH	55.0	40.0	13.0	31.0	48.0	38.0
GRA	66.0	32.0	80.0	16.0	74.0	24.0
HFA	89.0	29.0	49.0	34.0	66.0	32.0
LFG	6.0	10.0	52.0	54.0	11.0	15.0
MPE	103.0	54.0	28.0	11.0	57.0	27.0
TBE	25.0	19.0	15.0	7.0	22.0	16.0
TEC	253.0	275.0			253.0	275.0
WHI	34.0	40.0	57.0	32.0	53.0	33.0
WRI	42.0	46.0			42.0	46.0
Average	48.4	44.8	40.7	32.6	44.5	28.0

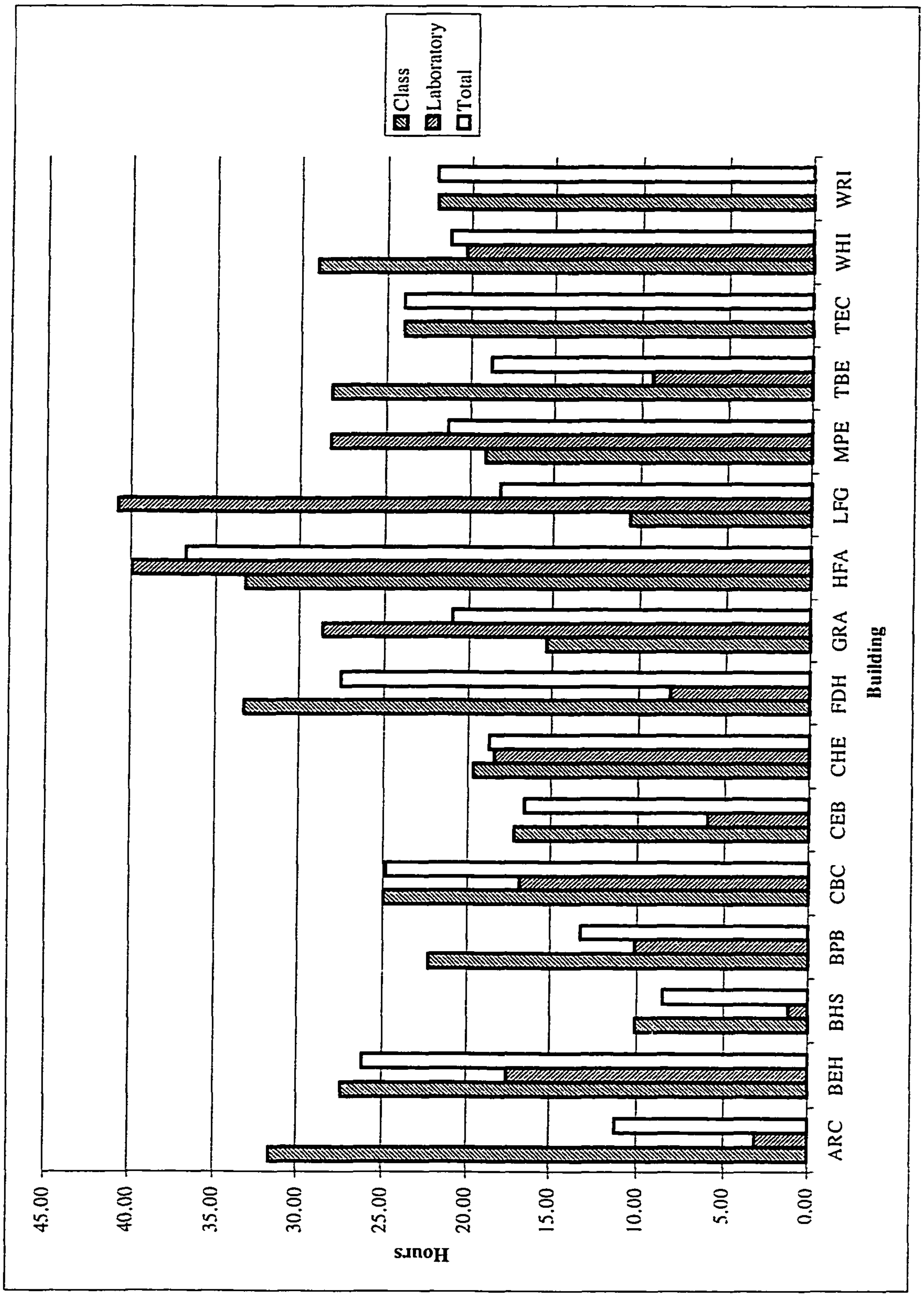


Figure 5.1. Daytime Room Utilization in Hours

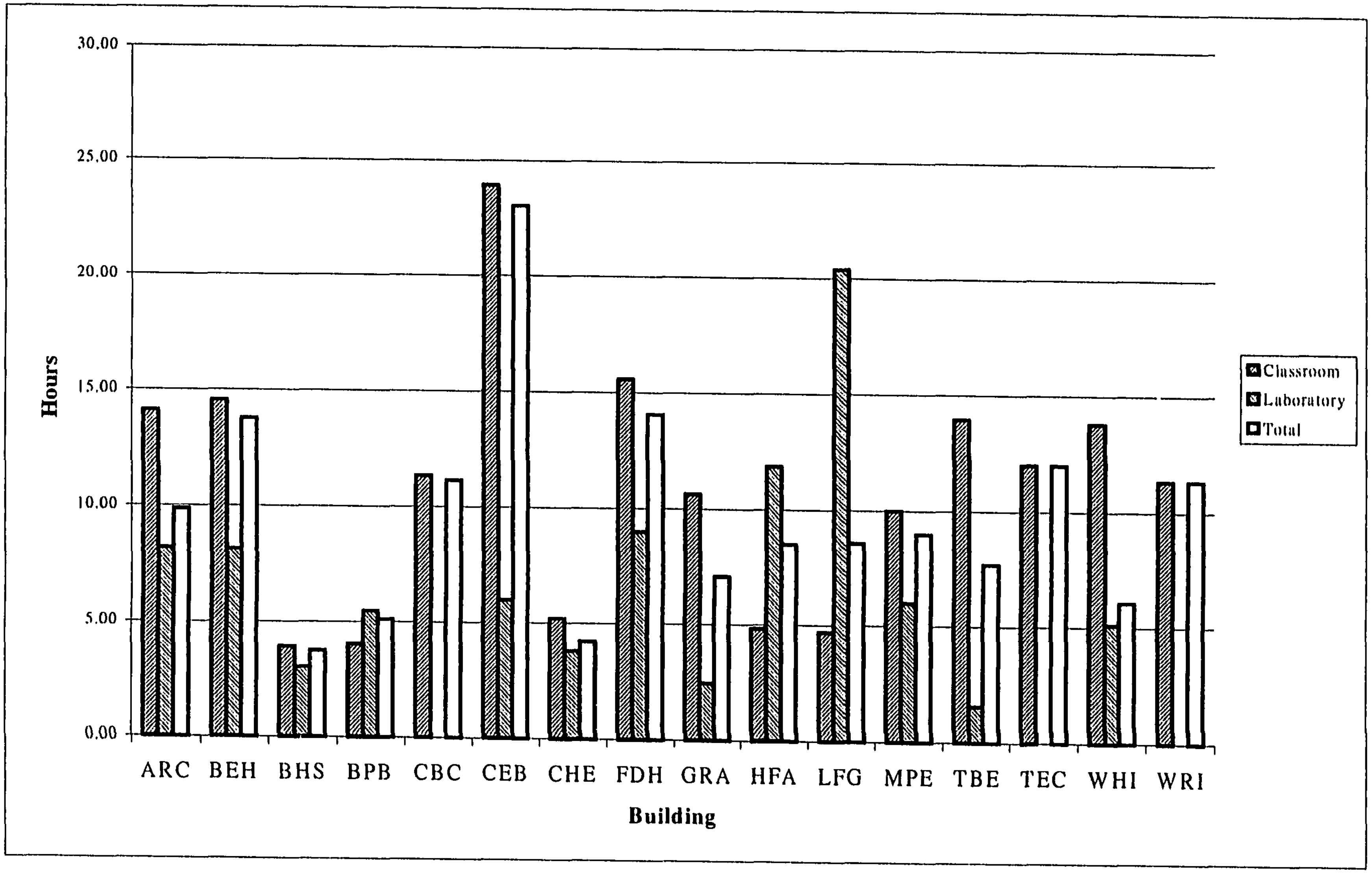


Figure 5.2. Evening Time Room Utilization in Hours

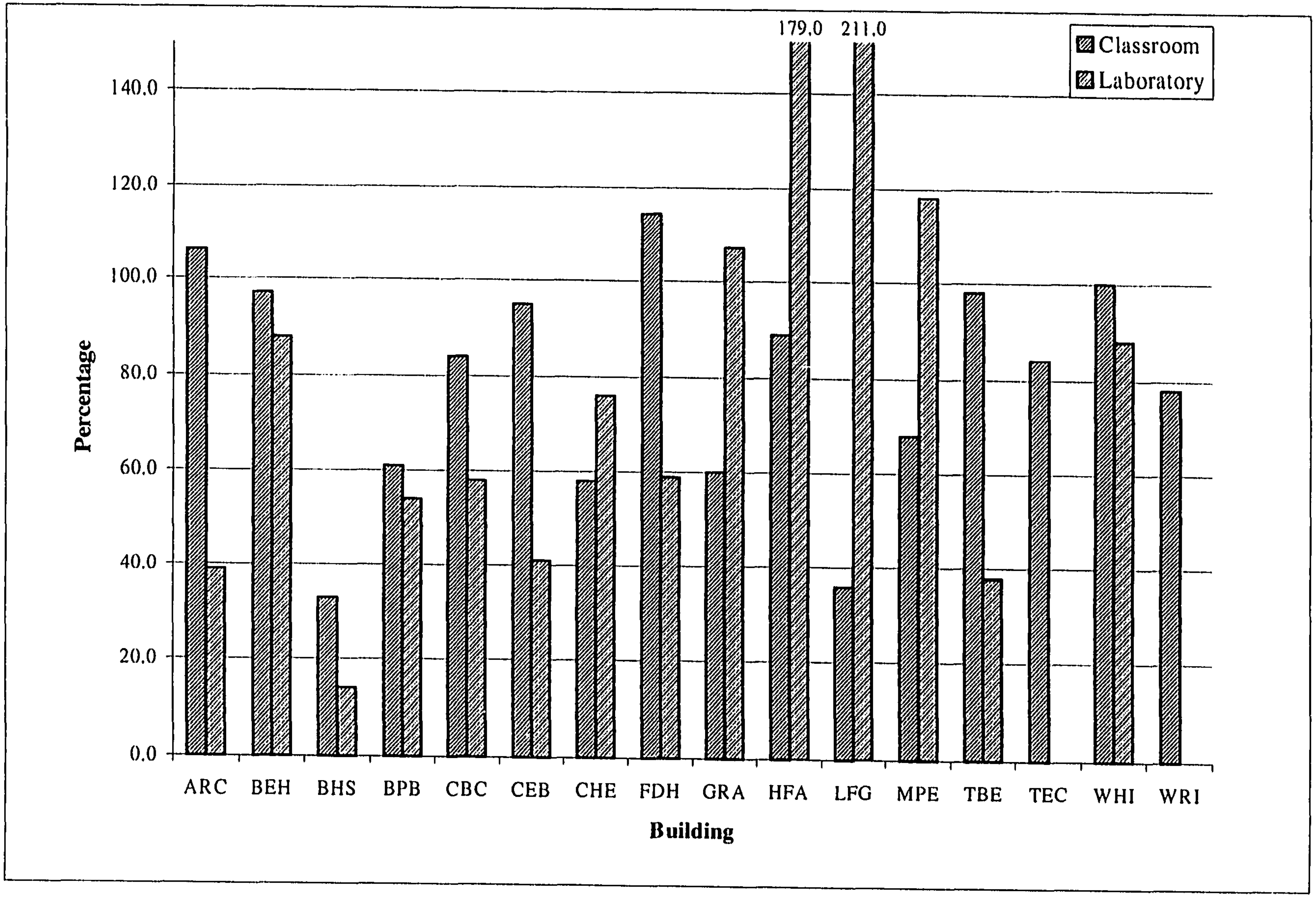


Figure 5.3. Percentage of Room Period Utilization

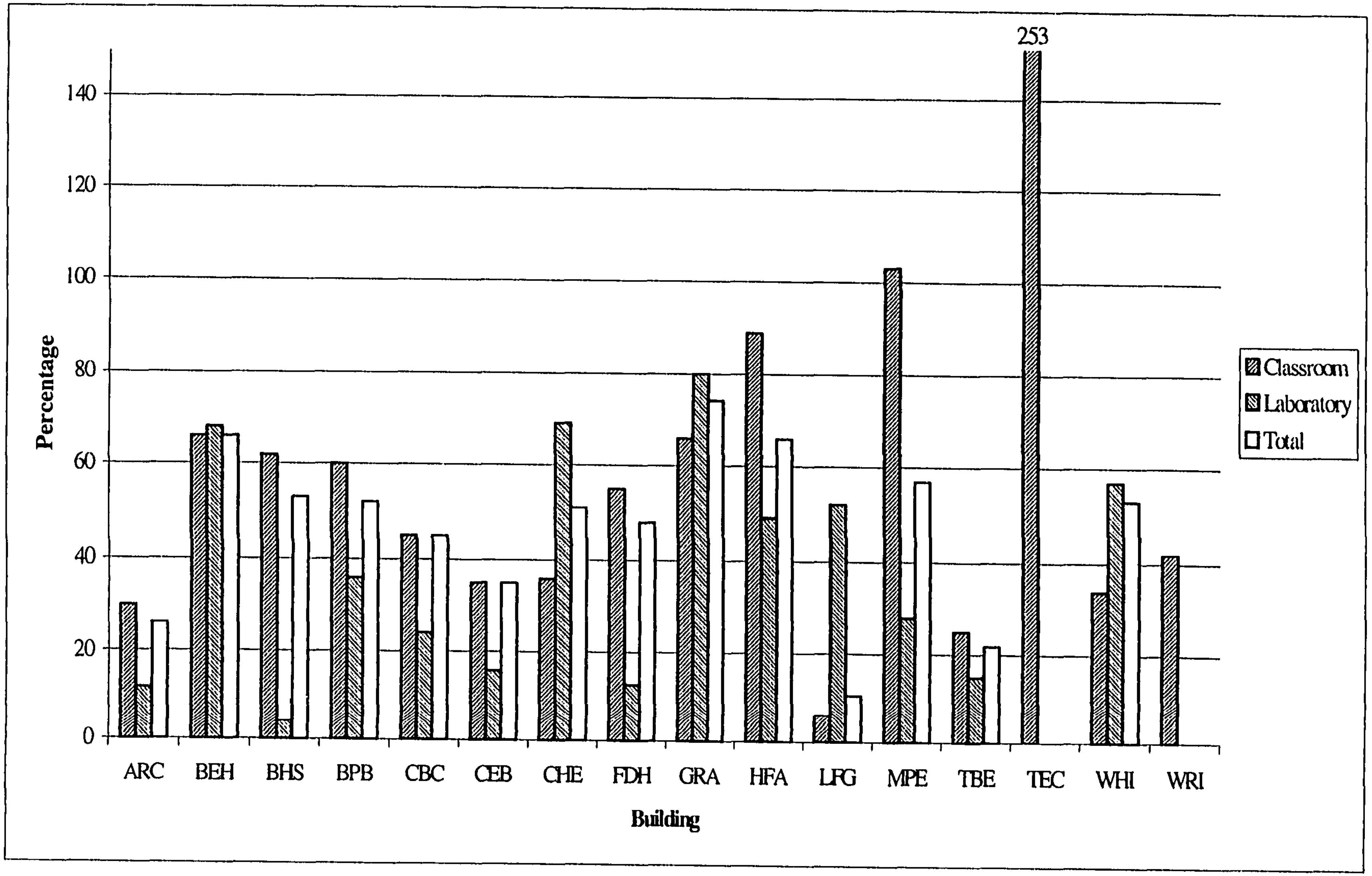


Figure 5.4. Percentage of Student Station Utilization During Daytime

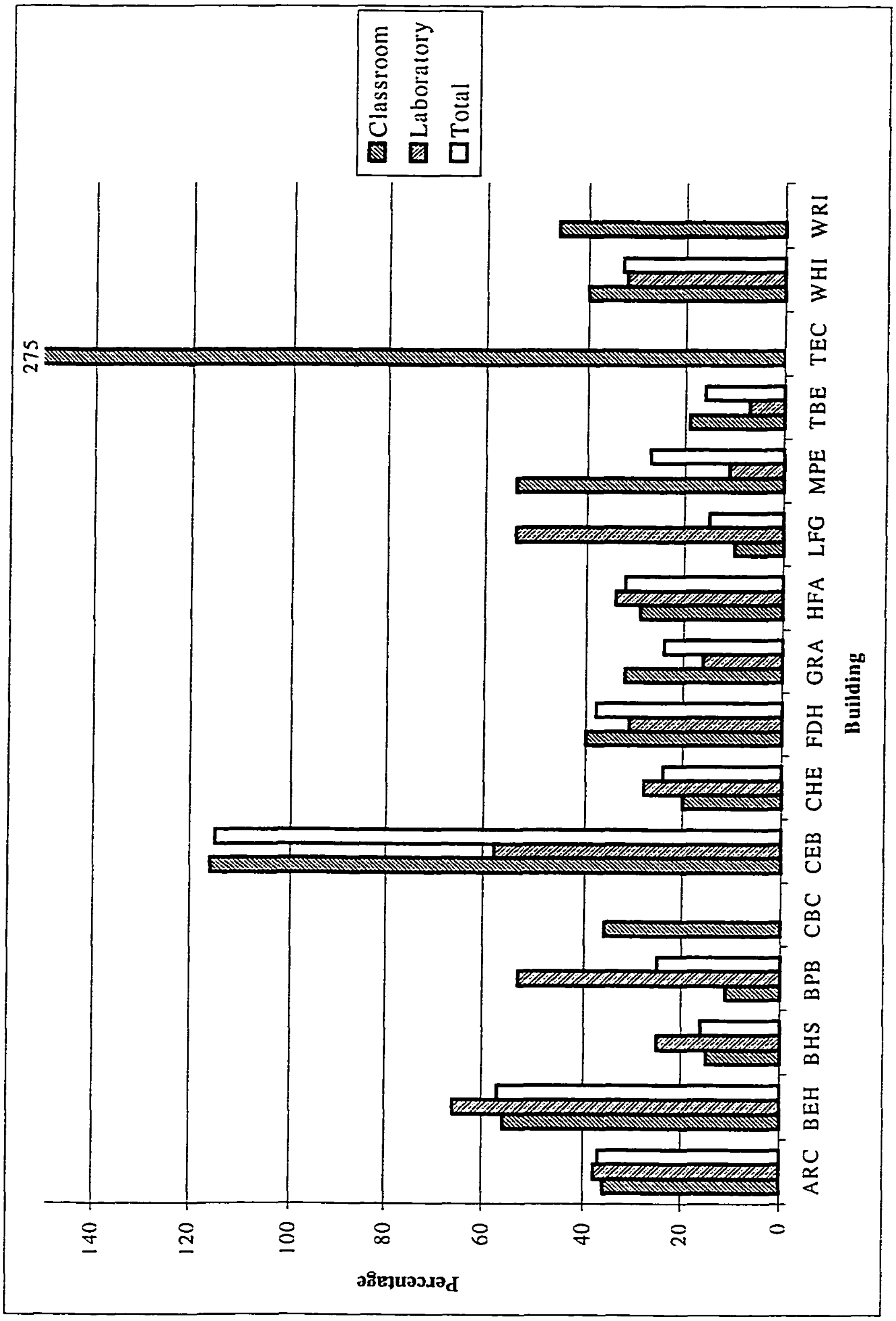


Figure 5.5. Percentage of Student Station Utilization During Evening Time.

5.3 Parking Utilization Measures

The results shown in Figures 5.6, 5.7 and 5.8 are based on the parking supply and demand collected for 17 parking lots. These parking lots are selected based on type of usage, that is each lot has either student, faculty, visitor, metered, resident or handicapped. The results are from the field surveys conducted as discussed in chapter 3. The number of parking spaces occupied were counted based on type of usage. An assumption was made that the same classes occur on Monday and Wednesday and similarly on Tuesday and Thursday. Hence counts were taken either on Monday or Wednesday and either on Tuesday or Thursday, and Friday. Data are collected three days a week and six different timings in a day. The timings were chosen based on the maximum number of students enrolled in a class at a time. Four different sets of times were selected during daytime and three sets of times selected during afternoon and evening sessions. Table 5.4 illustrates the timings of the schedule for the three different days.

Counts were taken for three different weeks to obtain data for analysis. Each parking lot's counts were entered into a database broken down by type of usage, time of the day, parking supply, and parking demand. A different set of database tables was created by day of the week i.e. for Monday, Tuesday and Friday. Based on the parking supply and actual demand observed the utilization of parking lots was calculated for the AM peak and the PM peak. The AM peak and the PM peak were selected based on the highest demand for parking during day and evening. For the purpose of this study, supply is defined as the sum of all parking spaces in a parking lot. Demand is equal to the sum of all parking spaces occupied in a parking lot. Of the 32 parking lots 17 parking lots were selected for field surveys. A complete list of parking supply is provided in Table 5.5. This is provided by the department of Public Safety. The total number of student parking spaces considered for this research are 4,863 and the total number of parking space's on-campus including all categories is 6,599. The percentage of parking utilization for a parking lot j can be formulated as shown in equation 3.16.

Utilization of Student Parking Lots on Mondays

The results of student parking utilization on Mondays are summarized in Table 5.6 and Figure 5.6. The average supply of parking spaces exceeded the average demand by 18.1 percent. Of the 17 parking lots, 11 parking lots include student parking spaces. Several lots are utilized 100 percent and a few others are better than 80 percent utilized. Only R lot has low utilization of 57 percent during the AM peak. During PM peak on lot is utilized for 100 percent and four others are utilized less than 50 percent. Hence the supply exceeded the demand.

The total percentage of AM and PM peak utilization is 90 percent and 40 percent respectively. Figure 5.6 illustrates that the percentage utilization during the PM peak of Blue lot, R lot, and Q lot is very low (below 40 percent). The possible reason could be because the three parking lots are not as accessible to classrooms or laboratories on campus as are other lots.

Utilization of Student Parking Lots on Tuesdays

The results of student parking utilization on a Tuesday are summarized in Table 5.7 and Figure 5.7. The total supply of parking spaces exceeded the total demand for spaces by 16 percent during the AM peak and 28 percent during the PM peak. Hence, the supply exceeded demand on Tuesdays. The total percentage of AM and PM peak utilization is 84 percent and 72 percent respectively. The total AM demand is higher than the total PM demand. There is a 100 percent utilization of three parking lots during the AM peak and many others are utilized more than 80 percent. Similarly, several lots are better than 80 percent utilized during the PM peak. Blue lot, Q lot and R lot utilization is below 50 percent during the AM peak and the PM peak.

The utilization of the AM peak and the PM peak on a Tuesday is similar as compared to Mondays. The percentage utilization of Blue lot, Q lot and R lot is low compared to other parking lots, which fall below 50 percent utilization. Figure 5.7 and Table 5.7 show that the percentage AM utilization of lot Q is lower than the percentage PM utilization which is an exceptional case as compared to the others. Hence it can be concluded that the utilization of Blue lot, Q lot and R lot is very low on Mondays and Tuesdays, and in general, the AM peak utilization is higher than the PM peak utilization. Again the reason for the low utilization of the three parking lots is because they are not as accessible to classrooms or laboratories on campus as are other lots.

Utilization of Student Parking Lots on Fridays

The results of student parking utilization on Fridays are summarized in Table 5.8 and Figure 5.8. The total supply of parking spaces exceeded the total demand for spaces by 45.5 percent during AM peak. In this case, only AM peak was taken into consideration because the number of classes on a Friday afternoon or during PM peak is comparatively low. Hence, PM peak was not taken into consideration. The toal AM utilization of student parking lots on Fridays is 51 percent which is comparatively low as compared to on Mondays and Tuesdays. There is a 100 percent utilization of two parking lots during the AM peak and most of the others are utilized on average of 60 percent. The percentage utilization of Blue lot, Q and R lots are low compared to other parking lots and they fall below 50 percent utilization as in the case on Monday and Tuesday. Figure 5.8 and Table 5.8 illustrates that the percentage AM utilization of Blue lot is 9 percent. Hence it can be concluded that the utilization of Blue lot, Q lot and R lot is very low on Monday, Tuesday and Friday. Again the location of these parking lots is away from classrooms and laboratory as compared to other parking lots on campus. In general, the utilization of parking lots on Friday is very less compared to utilization on Monday and Tuesday.

Total Parking Utilization on Mondays

The total parking utilization includes parking utilization of student parking spaces, faculty, handicapped, meter, resident and visitor parking spaces in a parking lot. This is calculated using equation 3.17 in Chapter 3. The total parking utilization is calculated for three days a week. They are Monday/Wednesday, Tuesday/Thursday, and Friday. Tables 5.9, 5.10 and 5.11 illustrate the results obtained from the total parking utilization.

Table 5.9 shows the total utilization of the parking lots on Mondays. The table illustrates that the overall utilization of the parking lots during the AM peak and the PM peak is 83.6 percent and 43.0 percent respectively. All the parking lots are utilized above 80 percent during the AM peak except for the R lot. During the PM peak the utilization of the parking lots varied with the lowest of 1.4 percent in Blue lot. The utilization of four parking lots is below 15 percent. Hence, the total PM utilization on Mondays is significantly low than the AM peak.

Total parking Utilization on Tuesdays

Table 5.10 shows the results obtained from the total parking utilization on Tuesdays. The results indicate that a significant number of parking lots were utilized above 80 percent. The utilization of Blue lot, Q lot and R lot is less than 50 percent on Tuesdays during the AM peak and the PM peak. The overall percent utilization of parking lots on campus during the AM peak is 81.1 percent and 74.2 percent during the PM peak. From the results it can be concluded that there is not much difference between the AM utilization and PM utilization on Tuesdays as compared to the utilization on Mondays.

Total Parking Utilization on Fridays

Table 5.11 shows the results obtained from the total parking utilization on Fridays. The overall utilization of parking lots on campus is 57 percent during the AM peak on Fridays. There is more than 80 percent utilization in seven parking lots. The least utilized parking lot on Fridays is the Blue lot followed by R lot, Green lot, and Q lot. From the results it can be concluded that the utilization of parking lots on Fridays is lower as compared on Mondays and Tuesdays.

Table 5.4. Schedule of Parking Lot Survey

Day of the week	Time of the Day						
	AM				PM		
Monday/Wednesday	8:45	9:45	10:45	11:45	5:45	7:00	
Tuesday/Thursday	8:45	10:15	11:45		1:15	5:45	7:00
Friday	8:45	9:45	10:45	11:45			

Table 5.5. Parking Supply by Type of Usage

Lots	Total	Staff	Students	Resident	Handi-capped	Reserved	Visitor	Meter	Load	M/C	General
A	495	67	397	0	11	1	0	5	1	5	8
Blue Lot	1,404	0	1,364	0	40	0	0	0	0	0	0
C	55	43	0	0	2	3	0	6	0	0	1
D	137	125	0	0	4	1	0	7	0	0	0
E	434	25	327	0	12	19	0	46	0	4	1
F	173	48	0	104	5	5	0	6	1	4	0
G	68	54	0	0	4	0	0	10	0	0	0
Green Lot	81	40	0	0	26	2	0	0	1	12	0
H	103	0	100	0	2	0	0	0	0	0	1
I	83	37	0	0	4	1	0	39	1	1	0
L	410	73	168	0	10	1	7	31	1	4	115
O	648	138	461	0	22	1	0	20	1	5	0
P	438	35	370	9	9	0	11	0	4	0	0
Q	300	0	220	0	16	2	0	0	0	0	62
R	213	0	200	0	5	0	0	8	0	0	0
Red Lot	1,510	143	1,256	36	24	0	0	47	0	3	1
V	47	0	0	0	0	0	47	0	0	0	0
Total	6,599	828	4,863	149	196	36	65	225	10	38	189

Table 5.6. Utilization of Student Parking Lots on Mondays

Parking Lot	AM Demand	PM Demand	Parking supply	% AM Utilization	% PM Utilization
A	397	312	397	100	79
Blue Lot	1,136	18	1,364	83	1
C			0		
D			0		
E	327	327	327	100	100
F			0		
G			0		
Green Lot	28	4	0		
H	100	94	100	100	94
I			0		
L	146	121	168	87	72
O	461	294	461	100	64
P	370	192	370	100	52
Q	219	12	220	100	5
R	115	25	200	57	12
Red Lot	1,076	560	1,256	86	45
V			0		
Total	4,375	1,959	4,863	90	40

Table 5.7. Student Parking Utilization on Tuesdays

Parking Lot	AM Demand	PM Demand	Parking supply	% AM Utilization	% PM Utilization
A	388	378	397	98	95
Blue Lot	688	573	1,364	50	42
C			0		
D			0		
E	327	326	327	100	100
F			0		
G			0		
Green Lot	250	66	0		
H	100	96	100	100	96
I			0		
L	132	160	168	79	95
O	445	431	461	97	93
P	353	322	370	95	87
Q	60	92	220	27	42
R	89	79	200	44	40
Red Lot	1,256	974	1,256	100	78
V			0		
Total	4,088	3,497	4,863	84	72

Table 5.8. Student Parking Utilization on Fridays

Parking Lot	AM Demand	Parking supply	% AM Utilization
A	256	397	64
Blue Lot	124	1,364	9
C			
D			
E	327	327	100
F			
G			
Green Lot			
H	100	100	100
I			
L	130	168	77
O	314	461	68
P	238	370	64
Q	86	220	39
R	42	200	21
Red Lot	848	1,256	68
V			
Total	2,465	4,863	51

Table 5.9. Total Parking Utilization on Mondays

Parking lot	AM Demand	PM Demand	Parking Supply	% AM Utilization	% PM Utilization
A	476	363	481	99.0	75.5
Blue lot	1,154	20	1,404	82.2	1.4
C	53	28	54	98.1	51.9
D	137	83	137	100.0	60.6
E	402	400	429	93.7	93.2
F	62	57	64	96.9	89.1
G	73	71	172	42.4	41.3
Green lot	68	9	68	100.0	13.2
H	100	94	102	98.0	92.2
I	79	66	80	98.8	82.5
L	242	201	290	83.4	69.3
O	635	426	642	98.9	66.4
P	434	237	434	100.0	54.6
Q	234	14	238	98.3	5.9
R	128	29	213	60.1	13.6
Red lot	1,326	812	1,506	88.0	53.9
V	42	45	47	89.4	95.7
Total	5,645	2,955	6,361	88.7	46.5

Table 5.10. Total Parking Utilization on Tuesdays

Parking lot	AM Demand	PM Demand	Parking Supply	% AM Utilization	% PM Utilization
A	470	447	481	97.7	92.9
Blue lot	699	575	1,404	49.8	41.0
C	53	50	54	98.1	92.6
D	137	131	137	100.0	95.6
E	403	399	429	93.9	93.0
F	160	158	168	95.2	94.0
G	68	68	68	100.0	100.0
Green lot	46	68	68	67.6	100.0
H	100	96	102	98.0	94.1
I	77	78	80	96.3	97.5
L	222	244	290	76.6	84.1
O	617	604	642	96.1	94.1
P	416	383	434	95.9	88.2
Q	70	98	238	29.4	41.2
R	94	88	213	44.1	41.3
Red lot	1,485	1,193	1,506	98.6	79.2
V	42	39	47	89.4	83.0
Total	5,159	4,719	6,361	81.1	74.2

Table 5.11. Total Parking Utilization on Fridays

Parking lot	AM Demand	Parking Supply	% AM Utilization
A	328	481	68.2
Blue lot	133	1,404	9.5
C	44	54	81.5
D	137	137	100.0
E	403	429	93.9
F	159	168	94.6
G	68	68	100.0
Green lot	17	68	25.0
H	100	102	98.0
I	76	80	95.0
L	216	290	74.5
O	446	642	69.5
P	293	434	67.5
Q	92	238	38.7
R	48	213	22.5
Red lot	1,012	1,506	67.2
V	45	47	95.7
Total	3,617	6,361	56.9

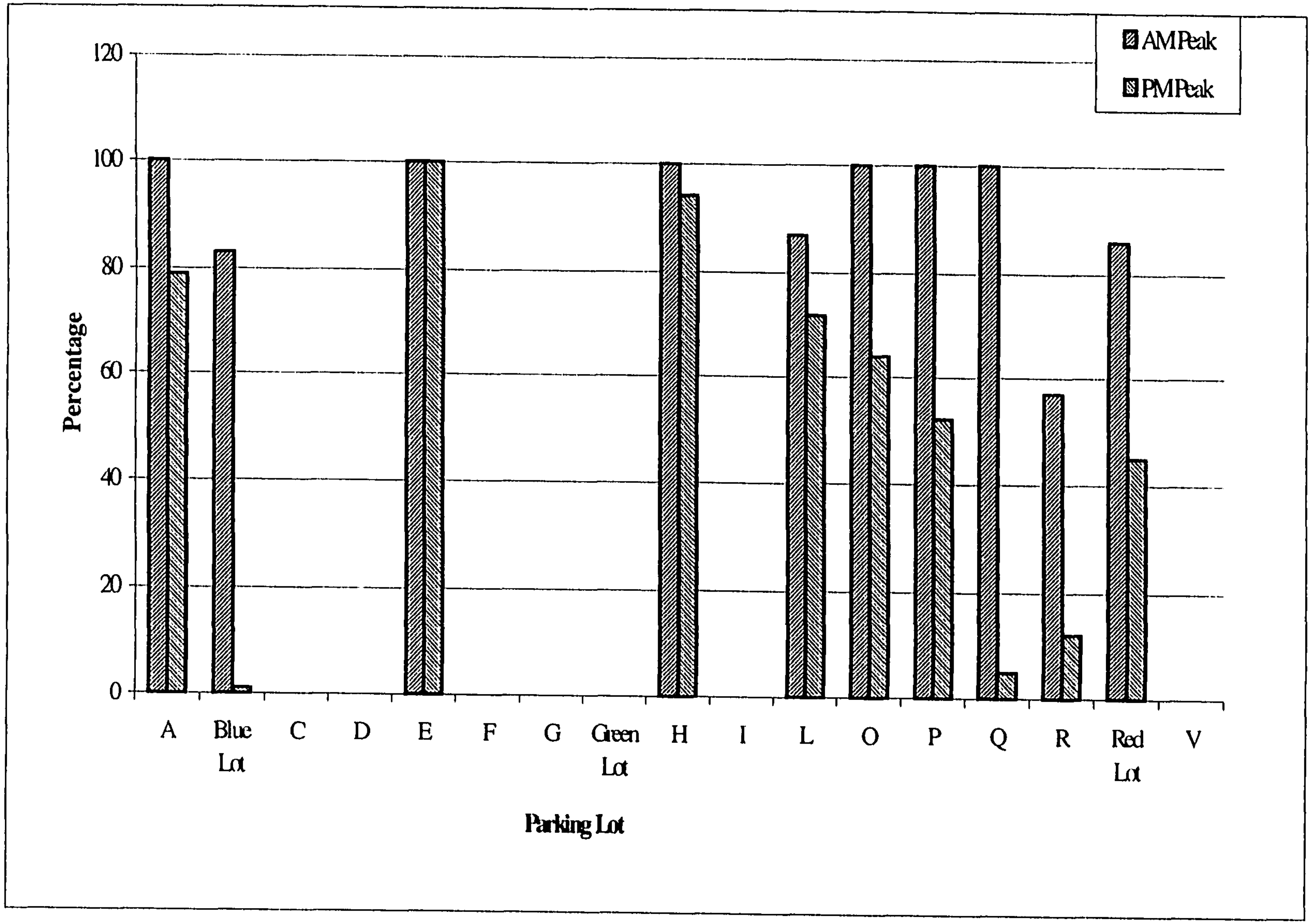


Figure 5.6. Utilization of Student Parking Lots by the AM peak and the PM peak on Mondays

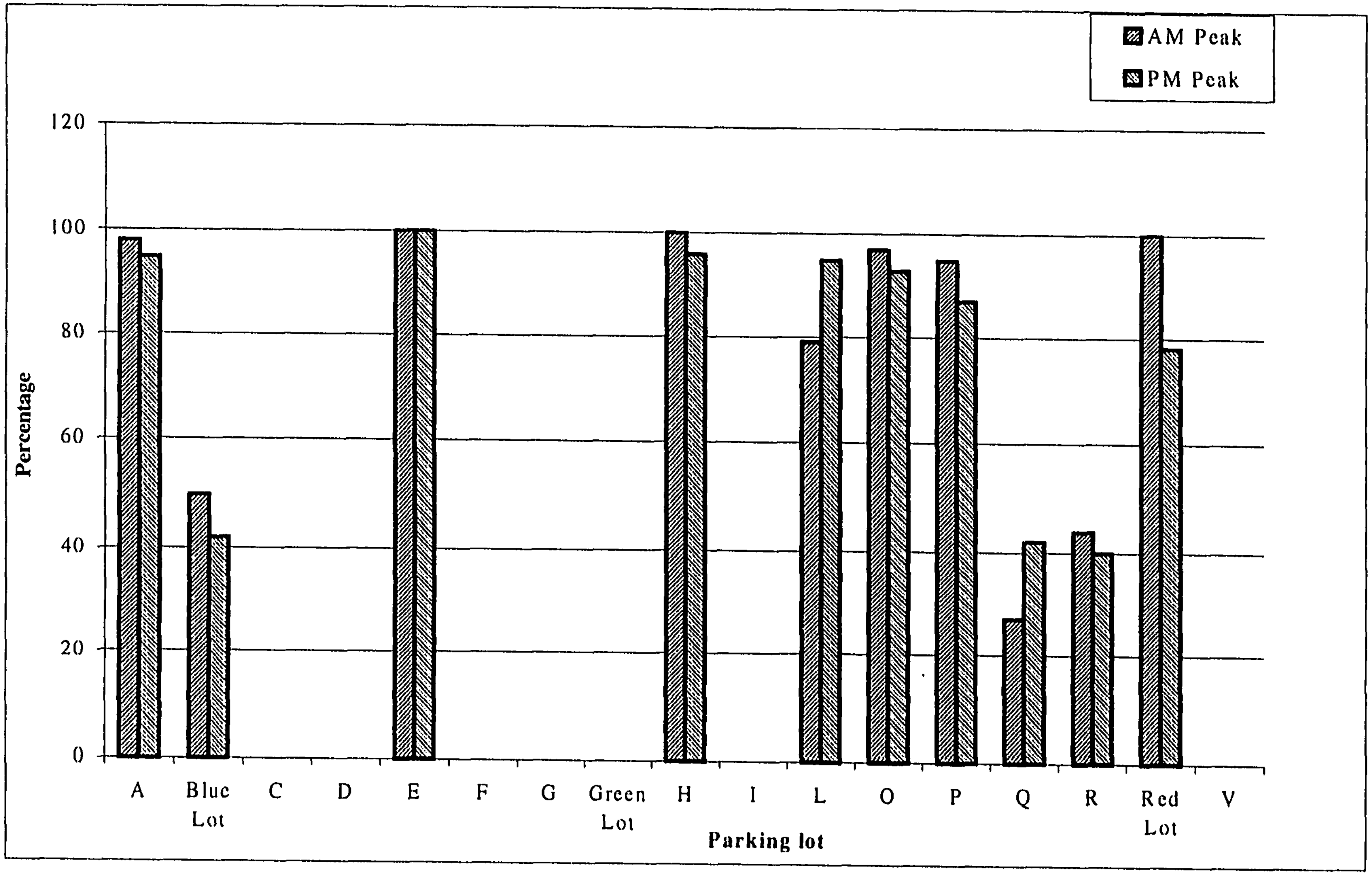


Figure 5.7. Utilization of Student Parking Lots During the AM peak and the PM peak on Tuesdays

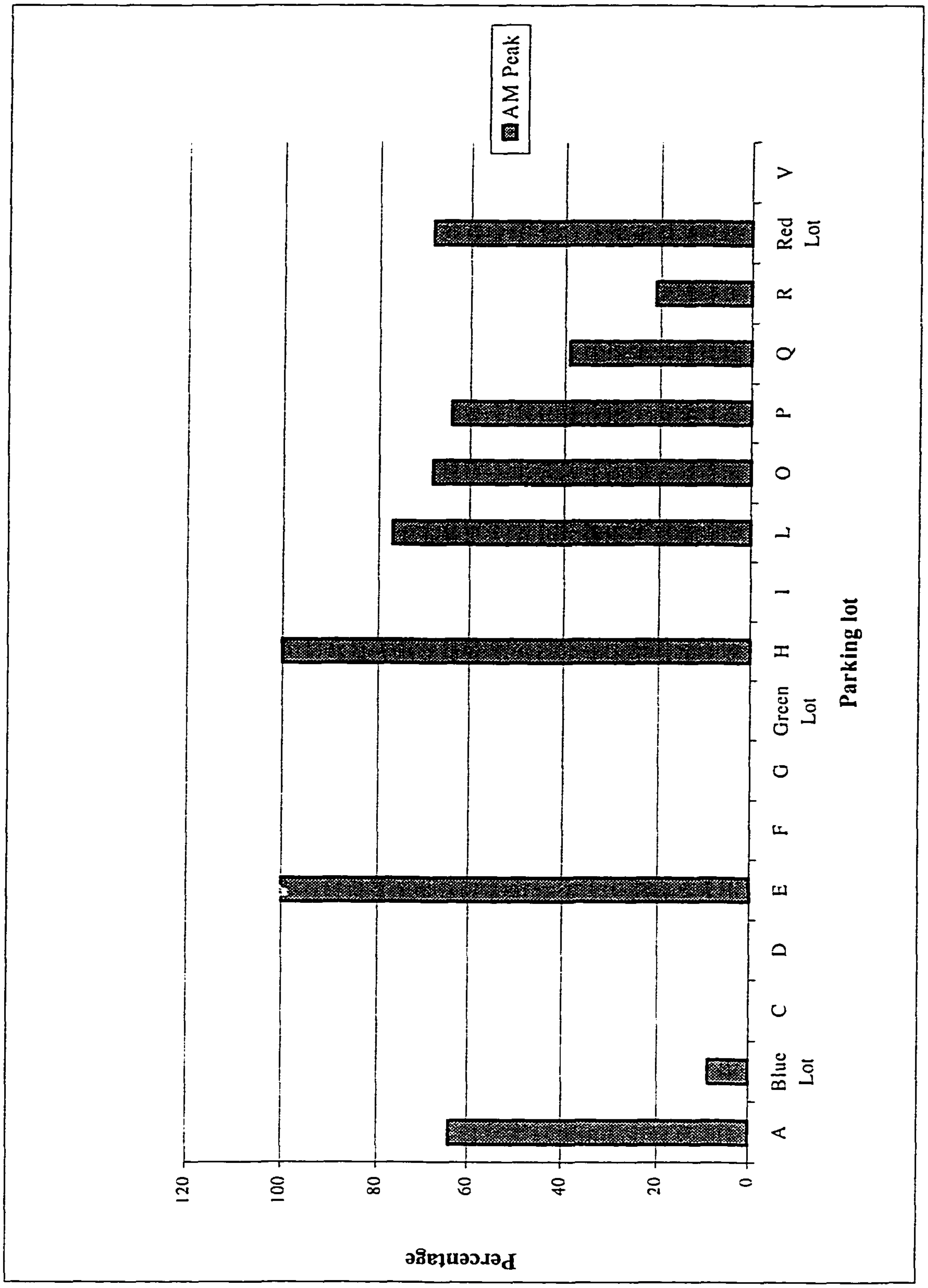


Figure 5.8. Utilization of Student Parking Lots on Fridays During the AM Peak

Results from In-class surveys

Using the parking demand numbers, the objective was to find out the general transportation mode of usage in the university and parking characteristics of the students. Results obtained from in-class surveys are illustrated in tables 5.12, 5.13, 5.14 and 5.15. Graphical representations of the measures are presented in figures 5.9, 5.10 and 5.11. In-class surveys were conducted in sixteen buildings for which utilization measures were calculated. A survey or a questionnaire was sent out to all the buildings as discussed in Chapter 3. Included in the survey profile were a set of questions. Data were acquired such that each building has atleast of 70 surveys. This was maintained in a database. The numbers presented below indicate the results obtained from these samples.

Table 5.12 illustrates the percentage of students parking on-campus and percentage of students parking off-campus. The total number of students parking on-campus is 80.9 percent and 10.3 percent park off-campus. From the Figure 5.9 it can be seen that 89.6 percent of students from BHS building park on-campus and 58.3 percent from GRA building park off-campus. These represent the highest and lowest percentages respectively of students parking on campus.

Table 5.13 and Figure 5.10 illustrate the mode of transportation students choose to come to UNLV. The survey consisted of different choices of mode of transportation. Based on the student's answers, the final output is shown. The total percentage of students drove to UNLV is 87.5 percent. It is estimated that a total of 0.9 percent carpool, 1.8 percent are dropped off, 1.6 percent use transit, 1.6 percent bicycle, and 5.1 percent walk to the university. Hence the trend in the university is that a very large percentage of students drive when compared to the usage of other modes of transportation, which are almost negligible. Out of the 87.5 percent who drove to UNLV, 80.9 percent park on-campus and 10.3 percent park off-campus. From Figure 5.10 it is evident that highest proportion of students who drive to university are from CHE building, and highest number of students who walk to university are from FDH building. Thus it can be concluded that more extensive programs should be conducted to encourage students to use transit and carpool or use other modes of transportation to reduce the demand at certain parking lots.

Tables 5.14 and 5.15 illustrate the results obtained from the question, where do the students park on-campus. Table 5.14 shows the number of responses from the survey and Table 5.15 shows the results in percentages. Figure 5.11 shows the parking lots used by the students from the BEH building. Following are the summary of the results. These results include percentage of students parking in a parking lot from their building. Maximum percentage of students using a parking lot is summarized here.

Lot A: 54.5 percent of students from CEB building and 54.2 percent from GRA building use parking lot A.

Blue Lot: Blue lot is used by students from BEH, CBC, BHS, FDH, TBE, and WHI buildings.

Lot C: Lot C does not contain student parking spaces, hence occupancy is very low in terms of percentages. Students from FDH and GRA building use C parking lot because of the buildings accessibility to C lot or it contains handicapped and metered spots.

Lot D: D lot similarly does not contain student spaces. Table 5.11 illustrate that students from BEH and FDH buildings use D parking lot. A possible reason for the student occupancy may be because D lot contains metered and handicapped spots.

Lot E: E is a student parking lot occupied by students from many buildings. They are BEH, CBC, CEB, CHE, FDH, GRA, TBE, and WRI. The major occupancy is from students of BEH, FDH and WRI buildings.

Lot F: F lot does not contain student parking spaces. It is occupied by students from BEH and WRI building. A possible reason for the student occupancy may be because F lot contains metered and handicapped spots.

Lot G: Similarly G is not a student parking lot, hence only 2.7 percent of students from BEH building use G lot. A possible reason for the student occupancy is because G lot contains resident, metered and handicapped spots.

Green Lot: Students from ARC, BEH, MPE, and WHI use Green lot. The percent usage of this parking lot is very low, the highest being 5.9 percent. A possible reason for his is because it may not be accessible to buildings as the rest of the parking lots.

Lot H: 47.9 percent of students from ARC building use H lot, as it is the nearest to the building. Others using H lot are students from BEH, CBC, MPE and WRI.

Lot K: K lot does not contain student parking spaces. Students from ARC building use K lot. A possible reason for the student occupancy is because K lot contains visitor, metered and handicapped spots.

Lot L: Students from BHS, CBC, CHE, MPE, and WRI use L lot. The maximum percentage being 11.5 percent used by CHE building

Lot M: M lot does not contain student parking spaces. Students using this lot are from BEH and MPE building. A possible reason for the student occupancy is because M lot contains metered and handicapped spots.

Lot O: Lot O is used by students from BHS, CBC, CHE, MPE, TBE, and WHI. The maximum occupancy is from BHS building. The percentage of students using lot O from BHS building is 86.4 percent followed by 61.5 percent from CHE building and 39,7 percent from WRI building. This is because of the accessibility of these buildings to O lot.

Lot P: Lot P is used by all the buildings except for students from ARC, and GRA building. The highest percentage of students being 71 percent from TBE building and followed by 25 percent from CBC building, as their first or last class is near by to P parking lot.

Lot R: Lot R is used by students from WRI building. The low utilization of R lot could be because it may not be accessible to buildings as the rest of the parking lots on campus.

Red Lot: 31.1 percent of students from BEH, 15 percent of students from CBC, 9.1 percent of students from CEB, 10 percent of students from FDH, 17.6 percent of students from MPE, 16.4 percent of students from WRI building use red parking lot.

Lot S: S lot does not contain student parking spaces. 1.4 percent of students from BEH building use S parking lot. A possible reason for the student occupancy is because S lot contains 30 metered parking spots.

Lot V: V lot does not contain student parking spaces. 1.8 percent from WRI building use V parking lot. A possible reason for the student occupancy is because V lot contains 47 visitor parking spots.

Lot Z: V lot does not contain student parking spaces. 4.2 percent of students from ARC building use Z parking lot. Similarly Z lot contains metered and handicapped spots.

Table 5.12. Percentage of Students Parking On-campus and Off-campus

Building	Total No. of Responses	On-campus		Off-campus		Not appllicable	
		Number	Percent	Number	Percent	Number	Percent
ARC	49	39	79.6	5	10.2	5	10.2
BEH	74	63	85.1	8	10.8	3	4.1
BHS	67	60	89.6	3	4.5	4	6.0
CBC	42	36	85.7	5	11.9	1	2.4
CEB	12	10	83.3		0.0	1	8.3
CHE	26	23	88.5	3	11.5		0.0
FDH	42	30	71.4	6	14.3	6	14.3
GRA	24	14	58.3	6	25.0	4	16.7
MPE	17	14	82.4	2	11.8	1	5.9
TBE	64	51	79.7	8	12.5	5	7.8
WHI	70	53	75.7	3	4.3	14	20.0
WRI	58	48	82.8	7	12.1	3	5.2
Total	545	441	80.9	56	10.3	47	8.6

Table 5.13. Mode of Transportation to UNLV

Building	Total No. of responses	Drove		Car pool		Drop off		Transit		Bicycle		Walk		Other	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
ARC	49	45	91.8	0.0	0.0	0.0	0.0	1	1.9	1	2.0	2	3.7	0.0	0.0
BEH	74	69	93.2	1	1.4	1	1.4	0.0	0.0	2	2.7	1	1.4	0.0	0.0
BHS	67	62	92.5	0.0	0.0	1	1.5	1	1.5	1	1.5	2	3.0	0.0	0.0
CBC	42	41	97.6	0.0	0.0	1	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEB	12	8	66.7	0.0	0.0	1	8.3	1	8.3	1	8.3	1	8.3	0.0	0.0
CHE	26	26	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FDH	46	34	73.9	2	4.3	0.0	0.0	0.0	0.0	0.0	0.0	9	19.6	1	2.2
GRA	24	19	79.2	1	4.2	1	4.2	0.0	0.0	0.0	0.0	2	8.3	1	4.2
MPE	17	15	88.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	5.9	1	5.9
TBE	64	56	87.5	1	1.6	1	1.6	2	3.1	3	4.7	1	1.6	0.0	0.0
WHI	70	53	75.7	0.0	1.4	2	2.9	3	4.3	1	1.4	8	11.4	2	2.9
WRI	59	53	89.8	0.0	0.0	2	3.4	1	1.7	0.0	0.0	1	1.7	2	3.4
Total	550	481	87.5	5	0.9	10	1.8	9	1.6	9	1.6	28	5.1	7	1.3

Table 5.14. Number of Students Parking On-campus (Units: Number)

Parking lot	Total Responses	ARC	BEH	BHS	CBC	CEB	CHE	FDH	GRA	MPE	TBE	WHI	WRI
A	38		7		1	6		3	13	1	2	2	3
B	1	1											
Blue lot	14		6	1	2			2			1	2	
C	2							1	1				
D	4		1					2					1
E	57		14		4	1	1	14	1		1		21
EPA parking	2									1	1		
F	2		1										1
Fdh	2						1	1					
Fra	1			1									
G	3		2										1
Green lot	3		1							1		1	
H	29	23	2		2					1			1
Interfaith	12	9	1		1		1						
K	2	2											
L	8			1	2		3			1			1
Lds institute	4	1	1		1							1	
M	2		1							1			
MPE parking	1											1	
N	1												1
O	104			57	3		16			2	1	25	
P	70		1	1	10	1	1	1		1	44	7	3
R	2												2
Red lot	52		23	1	6	1	1	4		3		4	9
S	2		1					1					
ThomasMac	9				2							6	1
V	1												1
Z	2	2											
Total	430	38	62	62	34	9	24	29	15	12	50	49	46

Table 5.15. Percentage of Students Parking On-campus (Units: Percentage)

Parking lots	ARC	BEH	BHS	CBC	CEB	CHE	FDH	GRA	MPE	TBE	WHI	WRI
A		9.5		2.5	54.5		7.5	54.2	5.9	3.2	3.2	5.5
B	2.1											
Blue lot		8.1	1.5	5.0			5.0			1.6	3.2	
C							2.5	4.2				
D		1.4					5.0					1.8
E		18.9		10.0	9.1	3.8	35.0	4.2		1.6		38.2
EPA parking									5.9	1.6		1.8
F		1.4										1.8
FDH						3.8	2.5					
FRA			1.5									
G		2.7										1.8
Green lot	2.1	1.4							5.9		1.6	
H	47.9	2.7		5.0					5.9			1.8
Interfaith	18.8	1.4		2.5		3.8						
K	4.2											
L			1.5	5.0		11.5			5.9			1.8
Lds institute	2.1	1.4		2.5							1.6	
M		1.4							5.9			
MPE parking lot											1.6	
N												1.8
O			86.4	7.5		61.5			11.8	1.6	39.7	
P		1.4	1.5	25.0	9.1	3.8	2.5	0.0	5.9	71.0	11.1	5.5
R												3.6
Red lot		31.1	1.5	15.0	9.1	3.8	10.0		17.6		6.3	16.4
S		1.4					2.5					
ThomasMac				5.0							9.5	1.8
V												1.8
Z	4.2											
Total	81.3	83.8	93.9	85.0	81.8	92.3	72.5	62.5	70.6	80.6	77.8	85.4

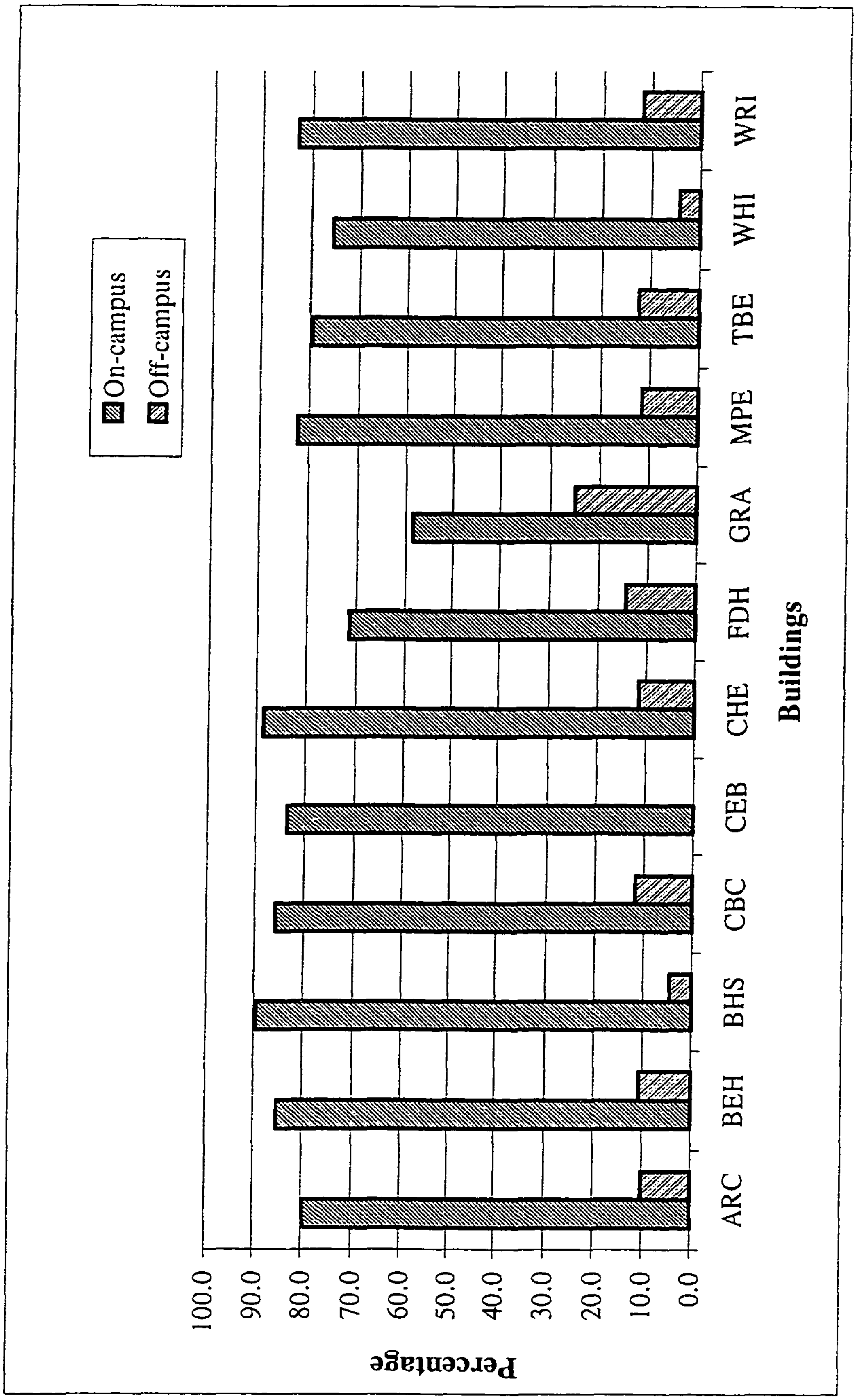


Figure 5.9. Percentage of Students Parking On-campus and Off-campus

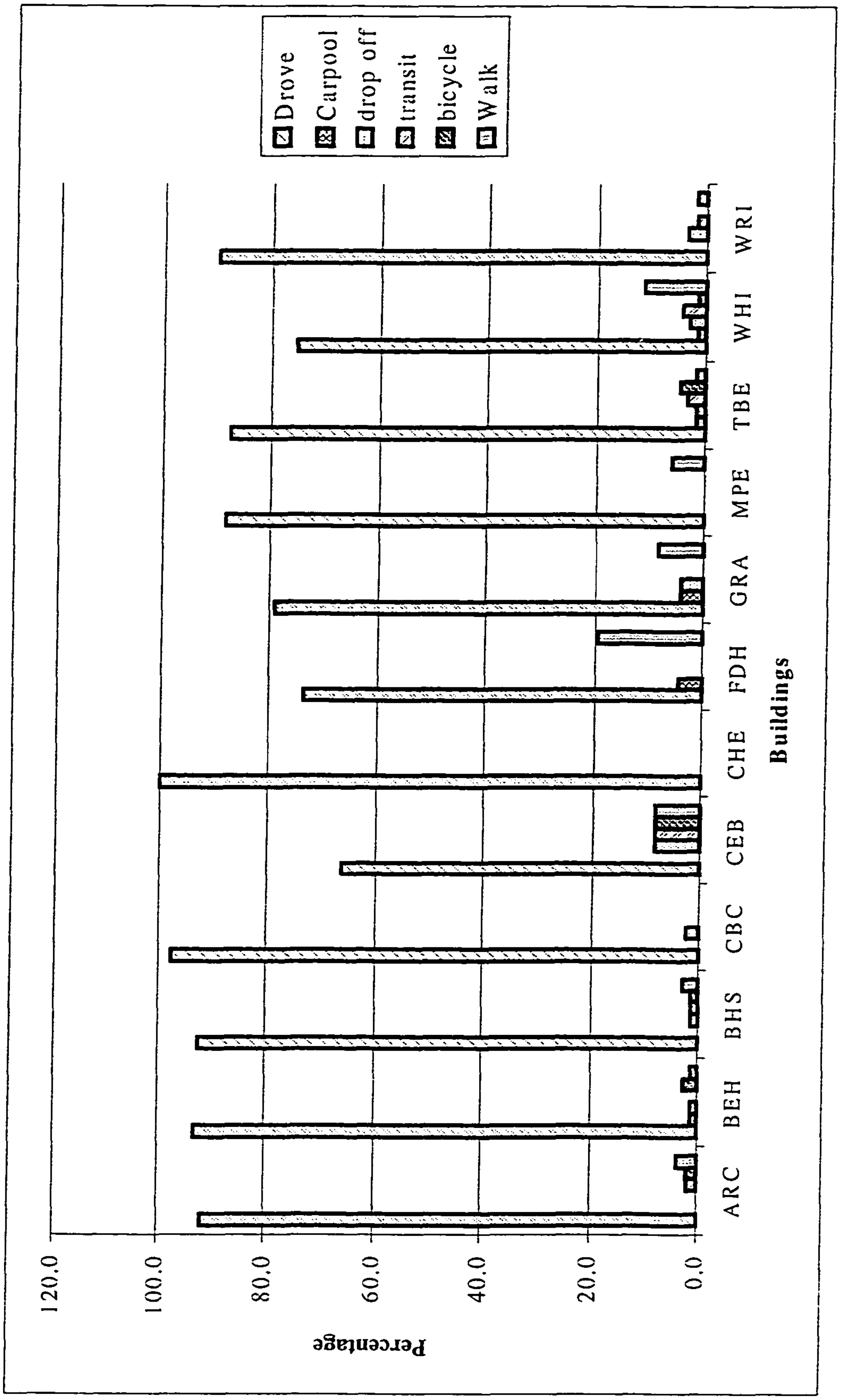


Figure 5.10. Mode of Transportation to UNLV

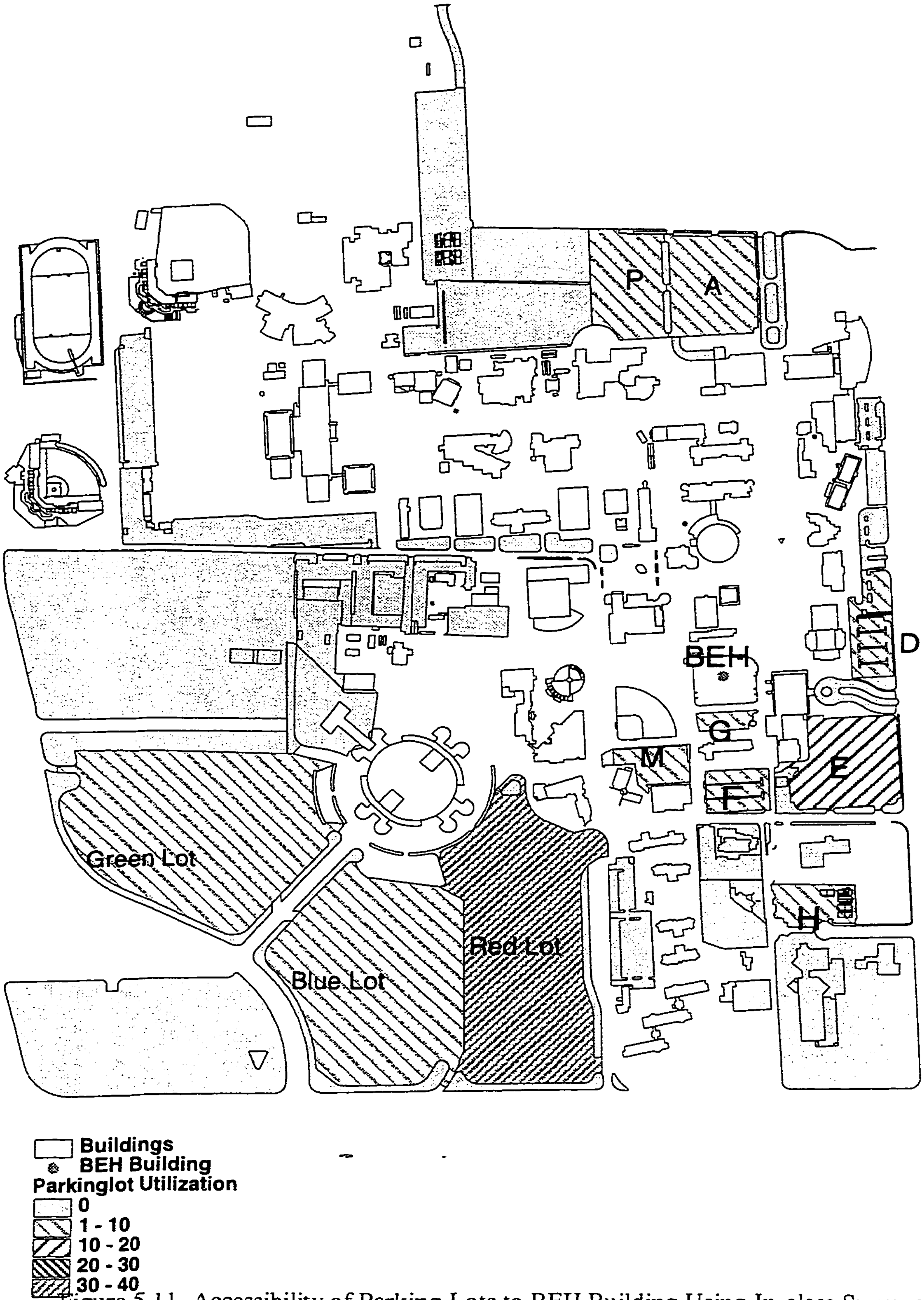


Figure 5.11. Accessibility of Parking Lots to BEH Building Using In-class Surveys

5.4 Development of the User Interface

The front-end application was developed using Visual Basic 6.0 as discussed in Chapter 3. Six different forms were developed based on their purpose of usage. The database is connected to the application using ODBC. Code is written in a code window for each form, which performs the analysis using the queries to give the output in a grid format. The various Forms are presented in the following Figures 5.11 to 5.16. Functionality of each form is discussed in the following sections.

Form1: The main Form shows the different options available in the application. The different options available are as follows:

- To query the database based on building, room no., usage and time of the day criteria.
- To calculate the room period utilization in hours
- To calculate the percentage of room period utilization.
- To calculate the percentage of student station utilization.
- To obtain the details of all rooms and buildings based on the number of station's criteria.

Labels are used to display the text on the form, option buttons are used to submit an option and a command button is used for submit button. Based on the choice made by using the above options, the required follow up form pops up. Figure 5.12 illustrates the basic form.

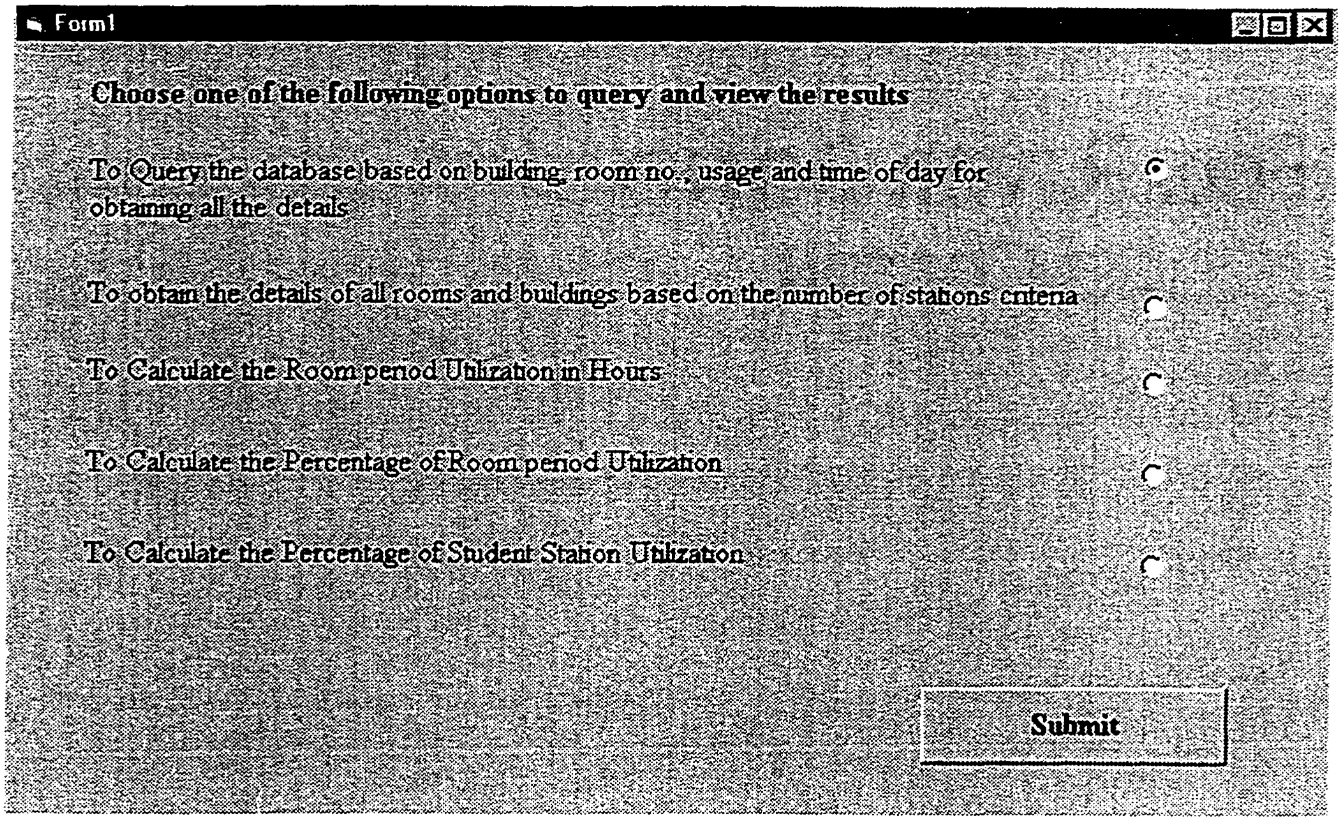


Figure 5.12. Basic Form to Choose Options

Form2: Form2 performs general queries based on the given options. Form2 consists of options to select buildings, room number, type of usage, time of the day, and day/evening options. Dropdown Combo boxes are used to select data for buildings, type of usage, time of the day, and day/evening. A text box is used to enter the room number of the building. Figure 5.13 shows the form 2 which is used to generate the basic data. The output of the form is in a grid format (MS Flexgrid). The out put of the table consists of the following:

Building: Gives the name of the building selected in the combo box.

Room No. Gives all the room numbers which satisfy the criteria.

Usage: Shows the usage of the rooms selected.

Monday: Shows whether a class is available on Mondays in a room with the given criteria. Here -1 represents that the class is scheduled on Monday.

Tuesday: Shows whether a class is available on Tuesdays in a room with the given criteria. Here 0 represents that the class is not scheduled on Tuesday.

Friday: Shows whether a class is available on Fridays in a room with the given criteria.

Enrolled: Shows the number of students enrolled in a room satisfying the given criteria.

Start time: Shows the start time of a class in a room.

End time: Shows the start time of a class in a room.

Day/Evening: Gives all the rooms in a building which start during day or evening based on the given criteria.

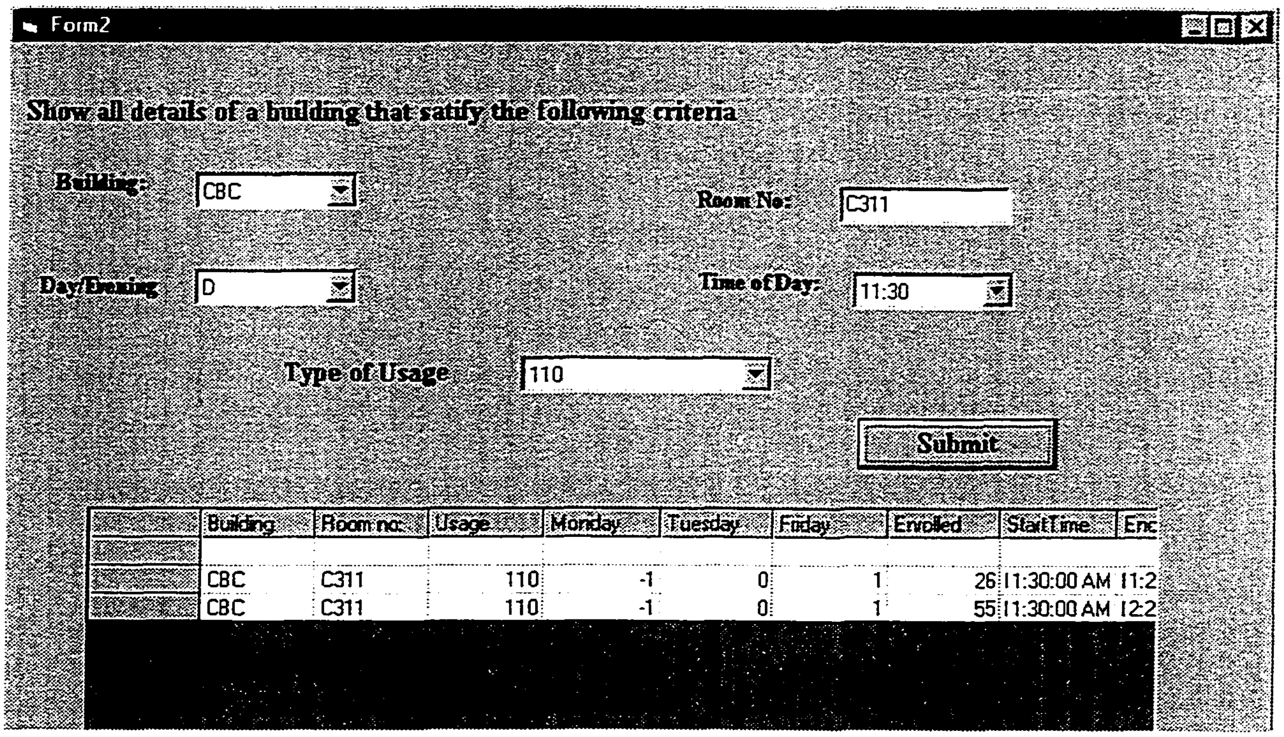


Figure 5.13. A Form to Retrieve General Data About Buildings

Analysis can be performed based on the following options:

- All building and all rooms
- One building and all rooms in the building
- Single room in a building

The above three different options are provided for all the different forms.

Form3: The third form is to provide input, used to calculate the Room period utilization in hours. The input for this form is building, room number, day/evening and type of usage. Dropdown combo boxes are used as the form of input for buildings and type of usage. A text box is used as the form of input for room number The output is given in a grid format giving box is used as the form of input for room number The output is given in a grid format giving the number of hours utilized by a classroom or a laboratory according to the given criteria. Figure 5.14 shows the form for room period utilization in hours. For example, consider TBE building, room no: B174 during daytime and usage is a classroom, the number of hours utilized during daytime is 42 hours per week. Similarly, consider CEB building, room no: 239 during daytime and usage is a classroom, the number of hours utilized during daytime is 24 hours per week. Consider a laboratory, i.e., 210 usage the room utilization is 28.2 hours per week during the daytime.

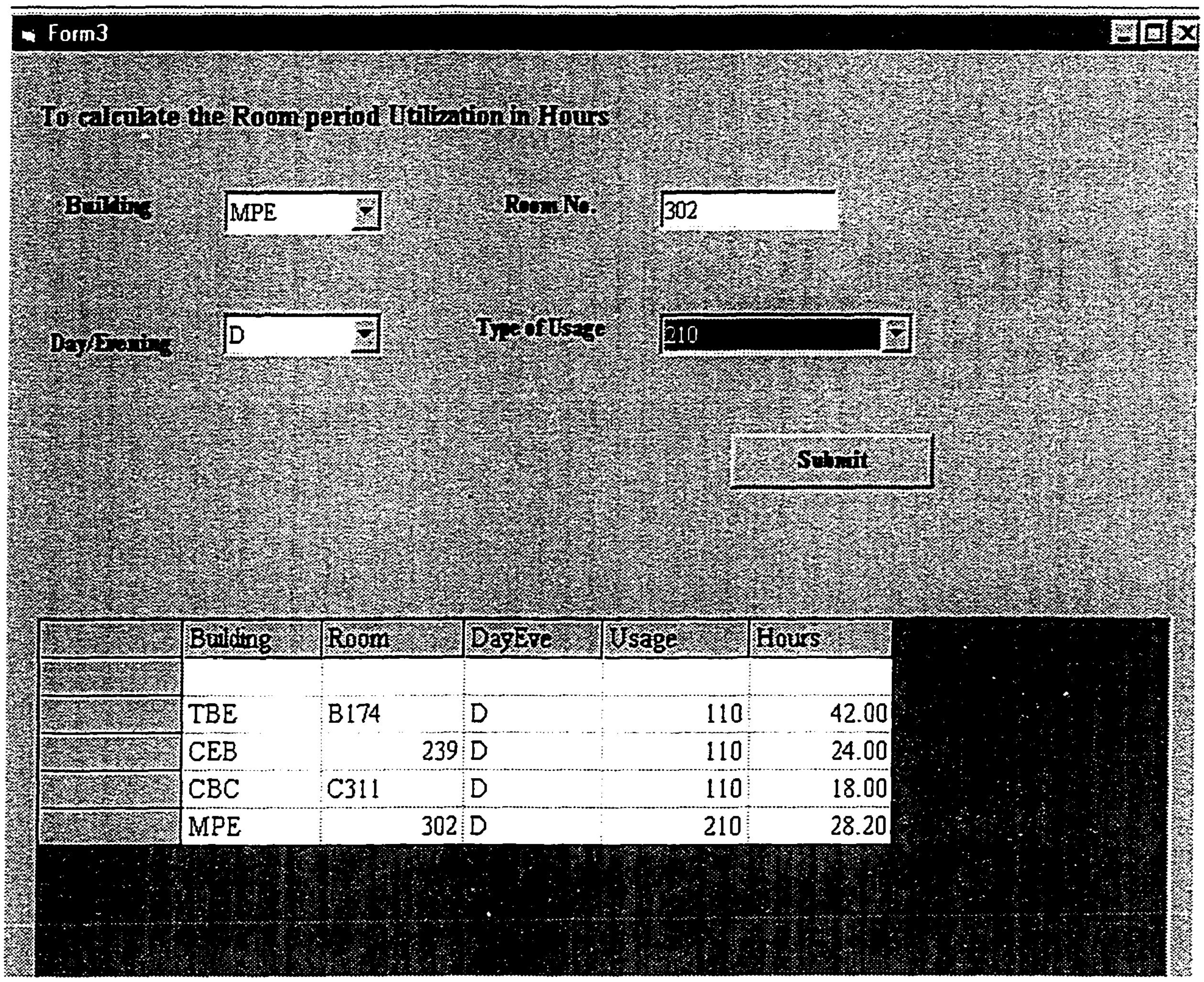


Figure 5.14. Form to Calculate the Room Period Utilization in Hours

Form4: Form4 calculates the percentage of room period utilization of classrooms and laboratories by the given criteria. The input for this form is building, room number, and type of usage. Dropdown combo boxes are used as the form of input for buildings and type of usage. A text box is used as the form of input for room number The output is given in a grid format giving the percentage of room utilized by a classroom or a laboratory according to the given criteria.

The analysis can be performed for all the buildings and rooms, or for all rooms in a building or for a single room in a building. The options can be chosen using a combo box. Figure 5.15 shows the form to calculate the percentage of room period utilization. As the figure shows the final output is the percentage utilization of classrooms in a building. Consider for example C311 room in the CBC building during daytime the percent utilization is 41.57 percent. Similarly consider room number 239 in CEB building the percentage utilization is presented based on day and evening time.

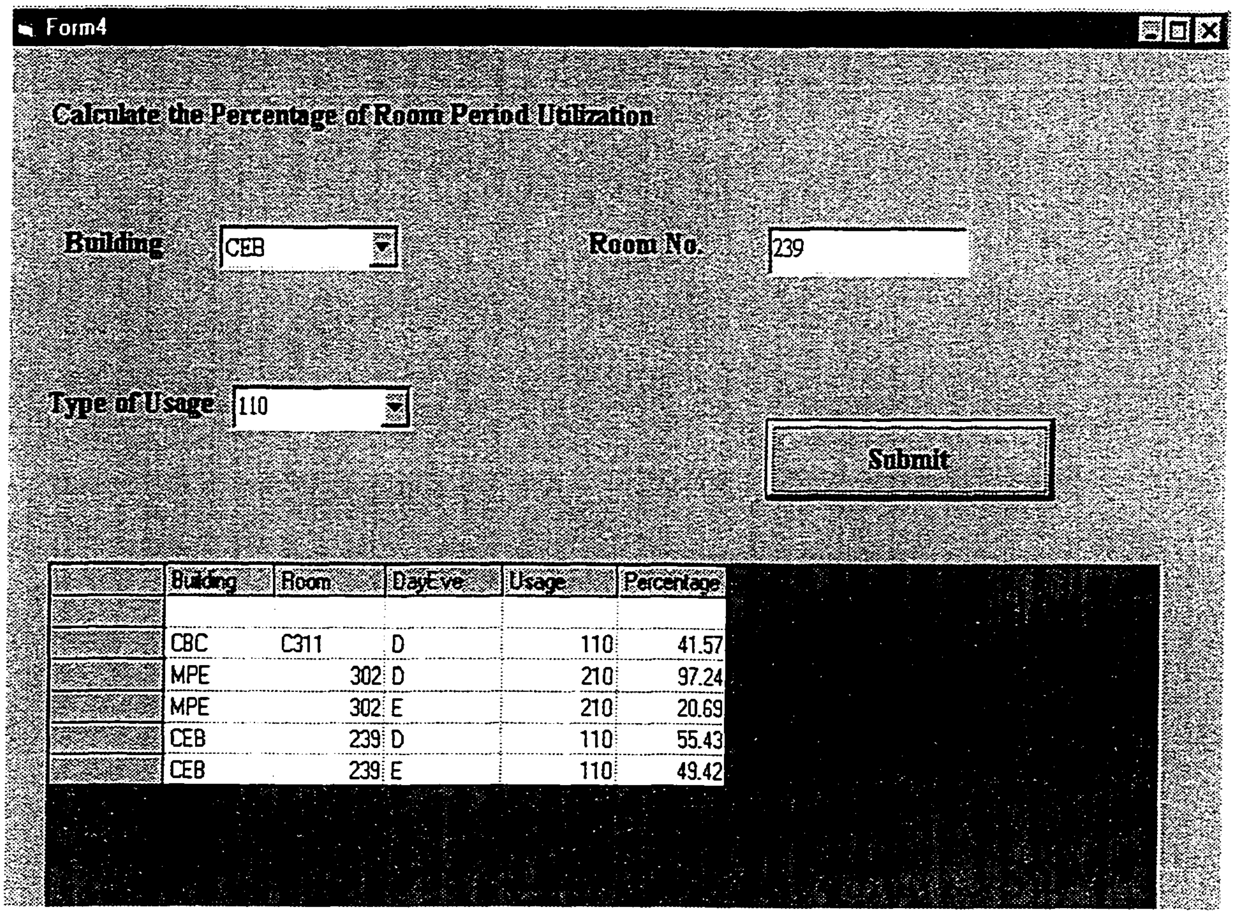


Figure 5.15. A Form to Query the Room Utilization in Percentage

Form5: Form5 calculates the percentage of student station utilization. This calculates the student occupancy in the buildings. The input for this form is building, room number, day/evening and type of usage. Dropdown combo boxes are used as the form of input for buildings and type of usage. A text box is used as the form of input for room number The output is given in a grid format giving the percentage of student stations utilized by a classroom or a laboratory according to the given criteria.

Similarly analysis can be done for all three options and the output is presented in a grid format. Figure 5.16 shows the form to calculate the percentage of student station utilization. Consider for example room 239 in CEB building, the student station utilization is 67 percent during daytime. Similarly consider MPE building and room number 302, the student station utilization is 28 percent.

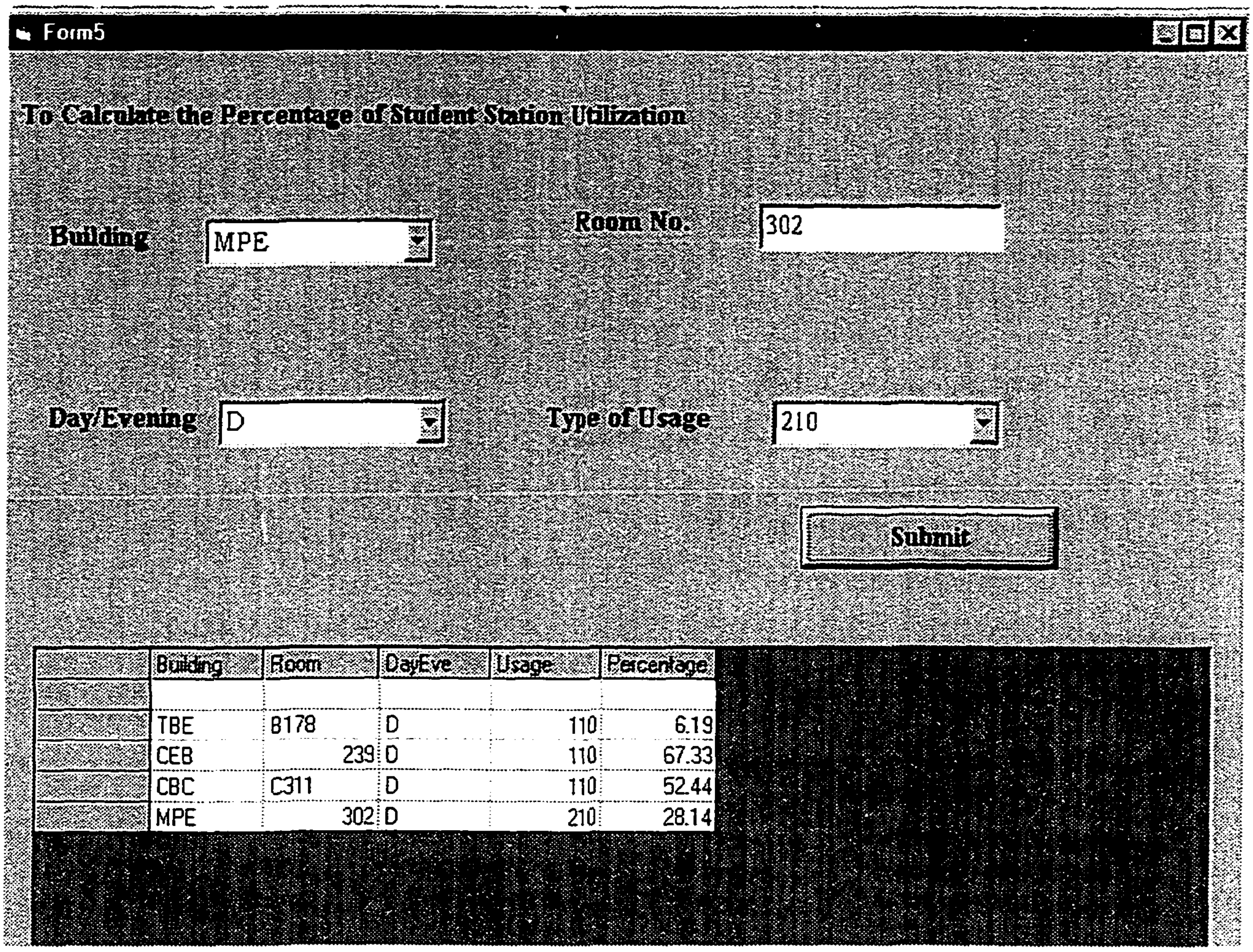


Figure 5.16. Form to Calculate the Percent Student Station Utilization

Form6: Form6 is developed to help determine how many rooms and how many buildings meet certain criteria. For example, how many rooms and buildings are used which has a capacity of between 40 and 50 stations. The criteria are number of stations. Such analysis can be performed for classrooms and laboratories. Figure 5.17 shows the form6. The input for this form is building, stations, day/evening and type of usage. Dropdown combo boxes are used as the form of input for buildings, station, day/evening and type of usage. The output is given in a grid format with the following fields shown as columns in Figure 5.17.

Building: Gives the name of the building selected in the combo box.

Room No. Gives all the room numbers which satisfy the criteria.

Usage: Shows the usage of the rooms selected.

Monday: Shows whether a class is available on Mondays in a room with the given criteria.

Tuesday: Shows whether a class is available on Tuesdays in a room with the given criteria.

Friday: Shows whether a class is available on Fridays in a room with the given criteria.

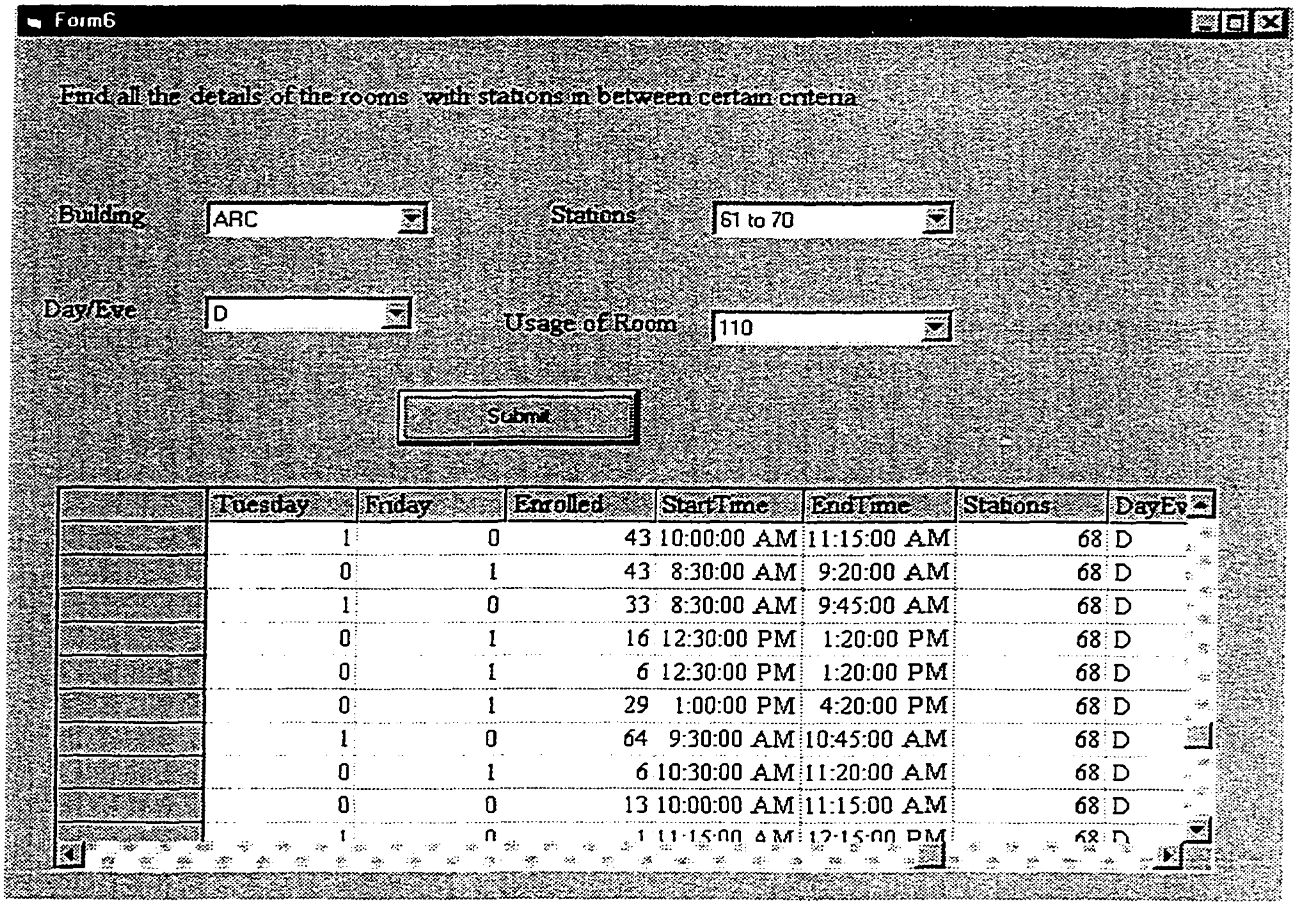
Enrolled: Shows the number of students enrolled in a room satisfying the given criteria.

Start time: Shows the start time of a class in a room.

End time: Shows the start time of a class in a room.

Day/Evening: Gives all the rooms in a building which start during day or evening based on the given criteria.

Stations: Shows the range of stations selected from the combo box.


Form6

Find all the details of the rooms with stations in between certain criteria

Building: ARC

Stations: 61 to 70

Day/Eve: D

Usage of Room: 110

Submit

Tuesday	Friday	Enrolled	StartTime	EndTime	Stations	DayEv
1	0	43	10:00:00 AM	11:15:00 AM	68	D
0	1	43	8:30:00 AM	9:20:00 AM	68	D
1	0	33	8:30:00 AM	9:45:00 AM	68	D
0	1	16	12:30:00 PM	1:20:00 PM	68	D
0	1	6	12:30:00 PM	1:20:00 PM	68	D
0	1	29	1:00:00 PM	4:20:00 PM	68	D
1	0	64	9:30:00 AM	10:45:00 AM	68	D
0	1	6	10:30:00 AM	11:20:00 AM	68	D
0	0	13	10:00:00 AM	11:15:00 AM	68	D
1	0	1	11:15:00 AM	12:15:00 PM	68	D

Figure 5.17. A Form to Specify Station Criteria

5.5 Construction of Accessibility Indices

The next step after identifying the methods used for developing building and parking utilization measures is the construction of the indices using various methods specified in the Chapter 4. The following sections discuss in detail the methodology involved in developing the accessibility indices by the three different methods and two different scenarios, discussion of results, and conclusions for each method.

5.5.1 Data Required

The basic data required for developing accessibility indices are information on the spatial distribution of the individual buildings, individual parking lots and their attributes (characteristics). These can be captured in a GIS environment as a building coverage and a parking coverage. Polygon coverages are built for buildings and parking lots. Point coverages of buildings and parking lots are required for constructing Thiessen polygon network the purpose of this study. Hence, an AML program is written which converts polygon coverages to point coverage. These coverages are commonly used for all the three different methods of developing accessibility indices.

5.6 Accessibility of Parking Lots to Buildings

Accessibility was defined as the most accessible area or region around a location. Accessibility indices can be developed using two different approaches. The first approach is to find out what parking lots are accessible to individual buildings and the second method is to find out what buildings are accessible to individual parking lots. The following section describes the methodology used to develop the indices based on the first approach, followed by results and analysis of results.

5.6.1 Thiessen Polygon Method

Thiessen polygons are constructed on the point coverage of the buildings. Each polygon consists of one building represented as a point and the area within that polygon is the most proximal (closer) area to that building than to any other building. The next step is to overlay the parking coverage on top of the Thiessen polygons to obtain all the parking lots in the proximal zone of each building. The proximal zone here is the most accessible to the building. This process is to be repeated for several buildings and parking lots. Hence an AML program is written to automate the process of constructing the accessibility indices. The output of this program is written to tables.

The next step is to calculate the number of parking spaces accessible to a building. Table 5.16 and Figure 5.18 illustrates the results from Thiessen polygon method for accessibility to parking spaces. Table 5.16 is constituted of different columns and rows. The first column is the different parking lots on campus and the first row represents the different buildings considered for the study. The table shows that 100 percent of H parking lot is accessible to ARC building and to no other building. 24.17 percent of the available student parking spaces in lot E are accessible to BEH and 75.83 percent of the available parking spaces are accessible to FDH. Likewise 53.1 percent of BHS building is accessible to the available student parking spaces in lot O, and 100 percent of R lot is accessible to BHS building. From the table it can also be illustrated that BPB building is not accessible to any of the parking lots. Similarly CBC bulding is accessible to six parking lots on campus out of which three parking lots do not contain student parking spaces. Note that the * in the table indicates that the parking lot is accessible to a building but does not have student parking spaces.

5.6.2 Buffer Method

A buffer is drawn around the building point coverages. The distance chosen for buffering is based on the walking time, say 5 minutes walking time from the parking lot to the building. The 5 minutes walking time is converted into a distance measure based on a 4 feet/second (2.7 meters/hour) walking speed. Hence, the distance to walk is 1,200 feet (365.76 meters) in distance. Hence the building coverage is buffered for a fixed distance of 1,000 feet (304.8 meters) and 1,500 feet (457.2 meters). The buffered region is overlaid on parking lot coverage. The parking lots which fall in the buffered region are the most accessible to that building. The output of this coverage is written to a table.

Based on the results obtained from the output table, the parking spaces accessible are calculated based on equation 4.1 as shown in Chapter 4. From the results tabulated in Table 5.17 and Figure 5.19 it can be illustrated that BEH building is accessible to 12 different parking lots. 100 percent of BEH building is accessible to E parking lot, 0.85 percent is accessible to H parking lot and 3.07 percent is accessible to Red lot. The rest of the parking lots do not contain student parking spaces. Similarly 100 percent of ARC building is accessible to H lot and 0.18 percent of ARC building is accessible to Red lot. Likewise CBC building is accessible to 9 different parking lots on campus. Three parking lots have student parking spaces. 49.51 percent, 9.9 percent and 3.14 percent of Red, Blue, Green lots are accessible to CBC building respectively.

5.6.3 Combination of Thiessen and Buffer method

Thiessen polygons are constructed around the point coverage for buildings to obtain the proximal area for each building. A buffer zone is constructed around each building to generate accessible area around the building. The buffer distance is chosen as explained in the previous section. The buffered regions are overlaid over the Thiessen polygons to obtain the most accessible region in the proximal zone of each building. The main objective is to determine which parking lots are in the most accessible area for each building. Hence the parking lot coverage is overlaid to obtain the parking lots which fall in the accessible region. This process is repeated for different buildings and buffer distances. As the process is repetitive, an Arc Macro Language (AML) program is written to automate the process. The AML is used to obtain the final results and store them in a table. The most accessible area of the parking lots is obtained as the final output.

The number of parking spaces is calculated based on the accessible area. The results are tabulated in Table 5.18 and Figure 5.20. The results obtained from this method are similar to Thiessen polygon method except for CBC building of Red, Blue, and Green parking lots and Red lot of ARC building. Consider for example ARC building. 100 percent of H parking lot is accessible to ARC building. Similarly, consider BEH building. 24.17 percent of E parking lot is accessible to BEH building whereas F, G and M parking lots are accessible but do not have student parking lots. Similarly consider Green parking lot. Green lot is accessible to one building on campus and only 48.56 percent of green lot is accessible to CBC building.

The results from Thiessen polygon method and combination of Thiessen and buffer method indicate that 6 out of 16 buildings do not have accessible parking lots in their accessible region. In a significant number of cases the parking lots which are in the accessible region do not have student spaces as they are exclusive for faculty, visitors, resident, and metered. The results obtained from buffer method are significantly different from the other two methods. The buffer method indicates that every building is accessible to a parking lot. The parking lot may or may not have student spaces in the accessible range.

5.7 Accessibility of Buildings to Parking Lots

The second approach to construct accessibility indices is to find out what buildings are accessible to a parking lot. The methods used to develop the accessibility indices are Thiessen polygon method, buffer method, and combination of Thiessen and buffer method. The methodology involved in developing the indices using the three methods is discussed in the following sections, followed by results and analysis of the results.

5.7.1 Thiessen Polygon Method

Thiessen polygons are constructed over the point coverage of parking lots. Each polygon consists of one parking lot represented as a point and the area in that polygon is the proximal (closer) area to that parking lot than to any other parking lot. The next step is to overlay the building coverage on top of the Thiessen polygons to obtain all the buildings in the proximal zone of each parking lot. The proximal zone here is the most accessible to the parking lot. The next step is to calculate the percentage of buildings accessible to a parking lot. The output is written to a table. Based on the results obtained from the output table, percentage areas of all the buildings, which are accessible to the parking lot, are calculated. The results are shown in Table 5.19 and Figure 5.21.

Table 5.19 consists of different columns and rows. The first column is the different parking lots on campus and the first row represents the different buildings considered for the study. The table depicts that 23.1 percent of ARC building is accessible to H parking lot. Likewise consider O parking lot. 100 percent of BHS building, 23 percent of BPB building, 73.6 percent of CHE building, 49.7 percent of TBE building, and 100 percent of WHI building is accessible to parking lot O. Similarly 37.5 percent of CEB building is accessible to A parking lot.

5.7.2 Buffer Method

A buffer is drawn around the parking lots to obtain accessible region around the parking lot. A buffer distance of 1,000 feet (304.8 m) and 1,500 feet (457.2 m) is used to draw a buffer. The building coverage is then overlaid on the buffered region. This gives the buildings which are accessible around the parking lot. The output is written to a table. Output table consists of all the buildings accessible and their respective areas and perimeters.

Results are summarized and tabulated in Table 5.20 and in Figure 5.22. For example, consider parking lot A. 100 percent of CEB building is accessible to A lot, 25.3 percent of CHE building, 4.6 percent of GRA building, 100 percent of HFA building, 2.5 percent of LFG building, 100 percent of TBE building, 56.8 percent of WHI building are accessible to A parking lot respectively. Similarly consider H parking lot. 100 percent of ARC building and 6.2 percent of BEH building are accessible to H parking lot. Similarly consider O parking lot. 100 percent of BHS, BPB, CHE, TBE, WHI buildings are accessible to O lot. Likewise 44.8 percent of CEB building, 10.2 percent of LFG building, and 82.3 percent of TEC building are accessible to O lot.

5.7.3 Combination of Thiessen and Buffer Method

The Thiessen polygons are constructed around the point coverage of parking lot. A buffer zone is constructed around each parking lot to generate accessible area around the parking lot coverage. The distance chosen for buffering is as explained in the previous section. This gives the accessible region in the Thiessen polygon or this gives the accessible region in a parking lot. The building coverage is overlaid over the accessible region. This gives all the buildings accessible to the parking lot. The output is written to a table.

The results are summarized and tabulated in Table 5.21 and in Figure 5.23. Consider for example parking lot A as shown in Figure 5.23. 37.9 percent of CEB building is accessible to parking lot A. Tables 5.19 and 5.21 indicate that out of 23 parking lots considered for analysis 11 parking lots do not have any buildings in their accessible region. Out of the 11 parking lots, 6 of them do not have student-parking spaces.

The results obtained from Thiessen polygon method are similar to the combination of Thiessen and buffer method. Consider for example TBE building to illustrate the differences between the three methods from tables 5.19, 5.20. and 5.21. From Table 5.19 and 5.21 it can be illustrated that 49.7 percent of TBE building is accessible to O parking lot and 50.3 percent of TBE building is accessible to parking lot P. Table 5.20 shows that 100 percent of TBE building is accessible to A, O and P lots. Likewise 3 percent of TBE building is accessible to N parking lot and 1.2 percent is accessible to parking lot R. Similarly consider CEB and CHE building. 37.9 percent of CEB building is accessible to parking lot A and 73.6 percent of CHE building is accessible to parking lot O. This indicates that some buildings are not completely accessible to the parking lots.

Table 5.16. Accessibility of Buildings to Student Parking Spaces Using Thiessen Polygon Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	MPE	LFG	TBE	TEC	WHI	WRI
A										7			93			
B										*						
C									*	*						
D								*								
E		24.17						75.83								
F		*														
G		*														
H	100															
K											*					
L											100					
M		*			*											
N					*						*					
O			53.1										10.7		36.2	
P													100			
Q											100					
R			100													
S								*								
V									*							
W	*				*											
Z	*															
RED	25.84				74.16											
BLUE	0.2				99.8											
GREEN					84.94											

Note: Units are in percentages

Table 5.17. Accessibility of Buildings to Student Parking Spaces Using Buffer Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	MPE	LFG	TBE	TEC	WHI	WRI
A			15.51	2.18		86.47	43.09		35.54	94.36		32.3	100	34.97	54.7	
B						*		*		*		*	*			
C		*				*		*	*	*		*				*
D		*						*	*	*		*				*
E		100						100								90.38
F		*			*			*								*
G		*			*			*				*				*
H	100	0.85														
K			*	*	*		*				*			*	*	
L			25.73	41.87			17.97				82.62			2.89	17.16	
M		*			*			*								*
N		*	*	*	*	*	*				*	*		*	*	*
O			100	100		64.13	100				54.65	22.31	100	68.21	100	
P			99.32	63.68		88.05	90.48		0.47	22.54		39.01	100	57.4	100	
Q											10.13					
R			72	31.66			13.38				0.7		20.69		60.57	
S		*						*	*							*
V		*				*		*	*			*				
W		*			*											
Z																
RED	0.18	3.07			49.51											
BLUE					9.9											
GREEN					3.14											

Note: Units are in Percentages.

Table 5.18. Accessibility of Buildings to Student Parking Spaces Using Combination of Thiessen and Buffer Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	MPE	LFG	TBE	TEC	WHI	WRI
A										7			93			
B										*						
C									*	*						
D								*								
E		24.17						75.83								
F		*														
G		*														
H	100															
K											*					
L											100					
M		*			*											
N					*						*					
O			53.1										10.7		36.2	
P													100			
Q											100					
R			100													
S								*								
V									*							
W	*				*											
Z	*															
RED	24.72				74.16											
BLUE	0.2				73.74											
GREEN					48.56											

Note: Units are in percentages

Table 5.19. Accessibility of Parking lots to Buildings Using Thiessen Polygon Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	LFG	MPE	TBE	TEC	WHI	WRI
A						37.5										
B						*				*						
C						*			*	*						
D								*								
E																
F																
G		*														100
H	23.1															
K																
L												100				
M					*											
N				*			*				*			*		
O			100	23			73.6						49.7		100	
P													50.3			
Q																
R																
S																
V																
W																
Z	*															
RED																
BLUE																
GREEN																

Note: Units are in Percentages.

Table 5.20. Accessibility of Parking lots to Buildings Using Buffer Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	LFG	MPE	TBE	TEC	WHI	WRI	Total
A						100	25.3		4.6	100	2.5		100		56.8		
B*						100		99.8	100	100	2.6						
C*						100		100	100	100	77.1					92	
D*		100						100	100	27.6						100	
E	30.6	100						100								100	
F*	53.7	100			100			100								100	
G*		100			100			100			53.3					100	
H	100	6.2															
K*			100	100			49					100			15.5		
L			100	84.5	100							100					
M*		100			100			84.8								100	
N*		16.4	100	100	100		100				100	94.2	3	100	94.2	79.1	
O			100	100		44.8	100				10.2		100	82.3	100		
P			100	36.2		100	100			7.3	12.4		100	29.9	100		
Q												100					
R			64										1.2		57.2		
S*		100						100	60.4							100	
V*						100		100	100	100	100					100	
W*	100				100												
Z*	100																
RED					100												
BLUE																	
GREEN																	

Note: Units are in Percentages.

Table 5.21. Accessibility of Parking lots to Buildings Using Combination of Thiessen and Buffer Method

	Building															
Lot	ARC	BEH	BHS	BPB	CBC	CEB	CHE	FDH	GRA	HFA	LFG	MPE	TBE	TEC	WHI	WRI
A						37.9										
B						*				*						
C						*			*	*						
D								100								
E																
F																
G		*														100
H	23.1															
K																
L												100				
M					*											
N				*			*				*			*		
O			100	23			73.6						49.7		100	
P													50.3			
Q																
R																
S																
V																
W																
Z	*															
RED																
BLUE																
GREEN																

Note: Units are in Percentages.

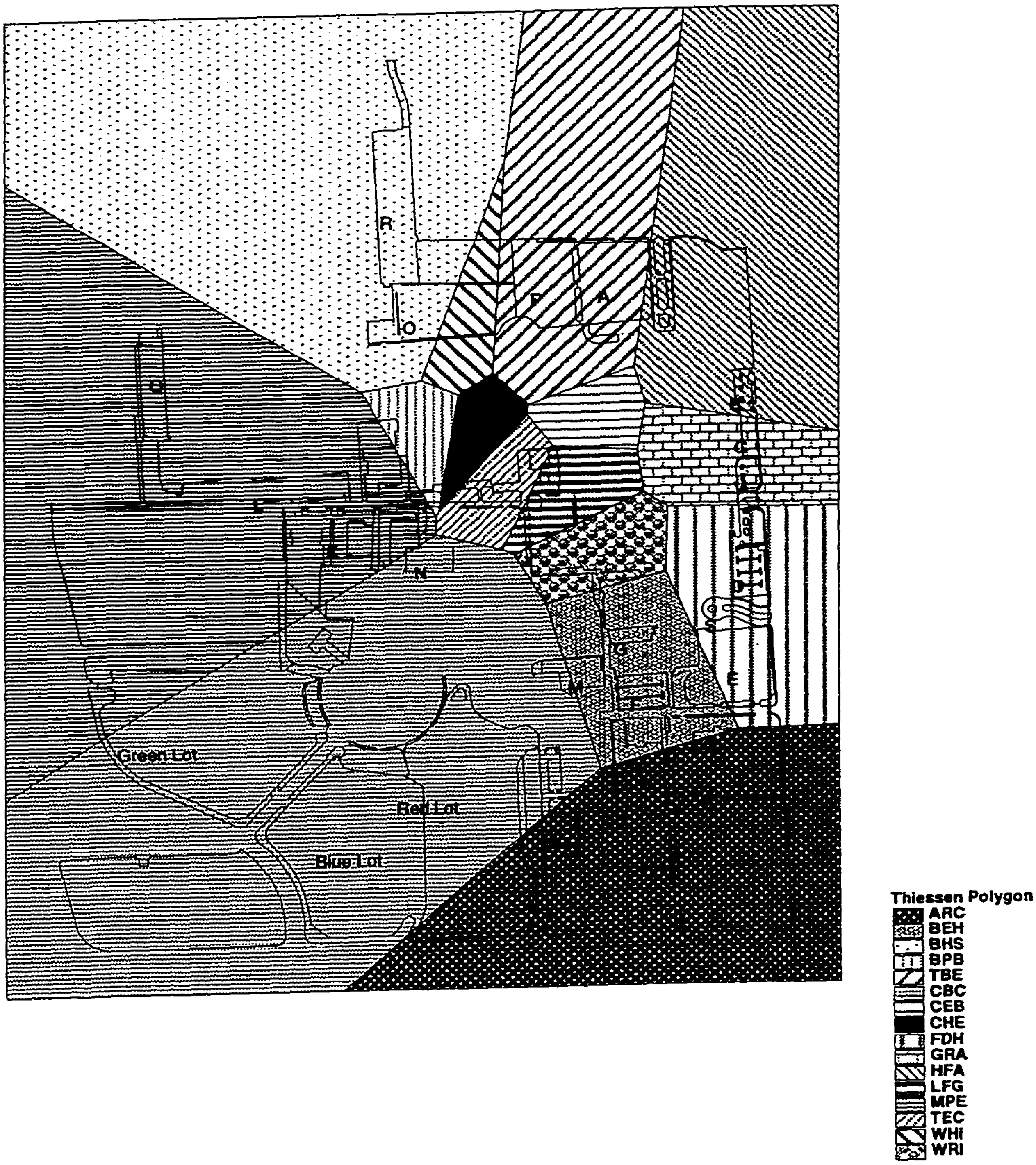


Figure 5.18. Accessibility of Buildings to Student Parking Spaces Using Thiessen Polygon Method

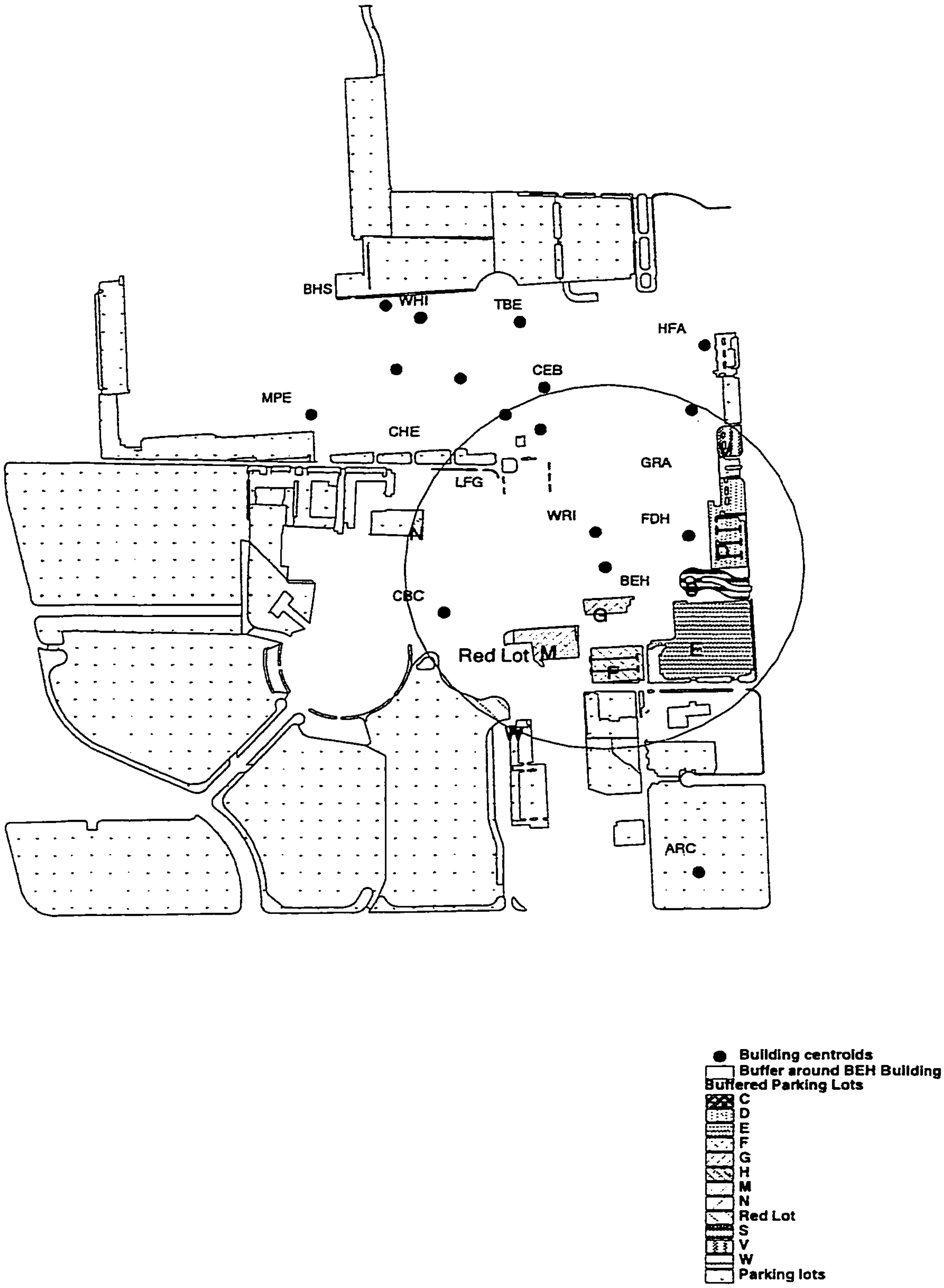


Figure 5.19. Accessibility of BEH Building to Student Parking Spaces
Using Buffer Method (Buffer distance: 1,000 ft)

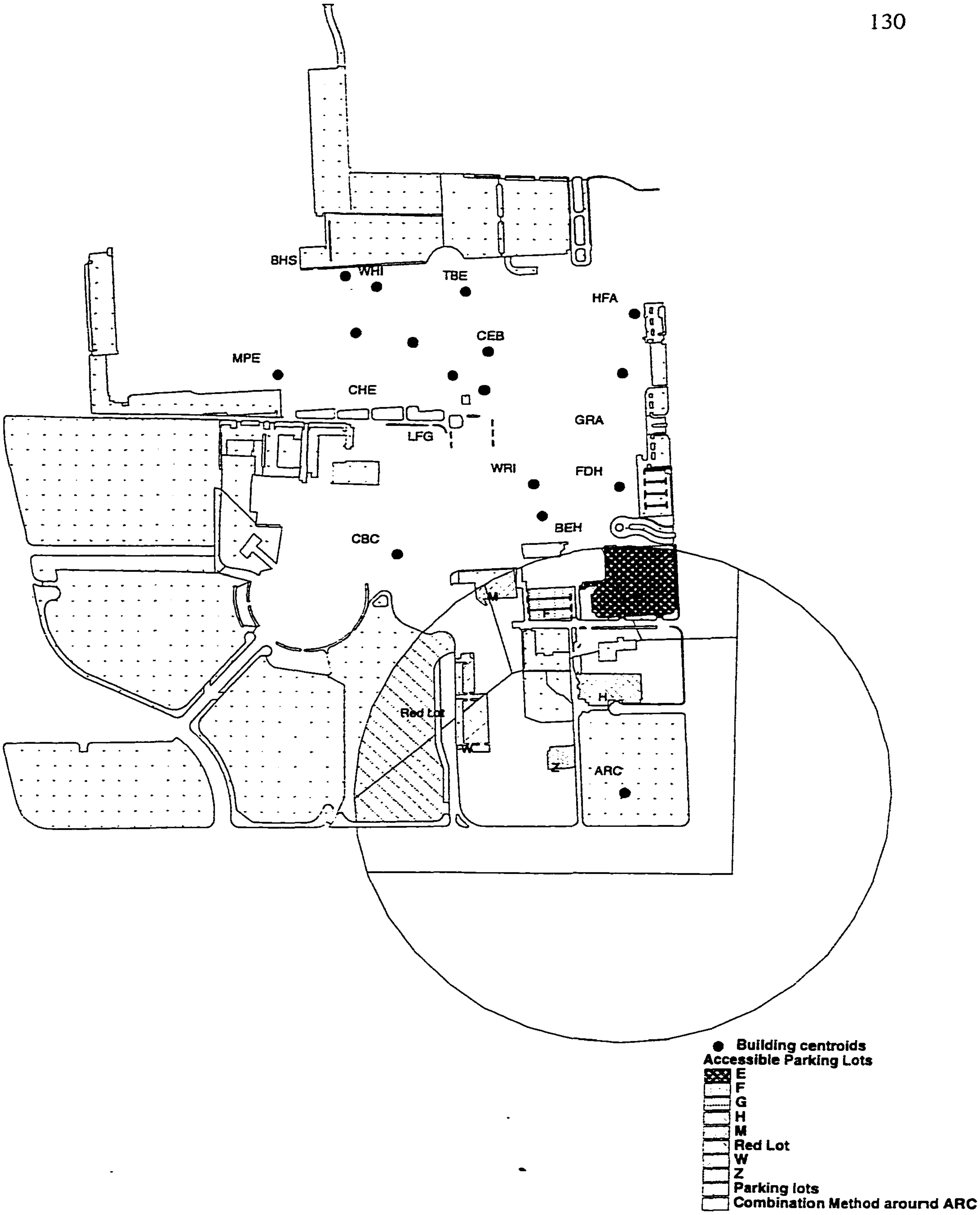


Figure 5.20. Accessibility of ARC Building to Student Parking Spaces Using Combination Method (Buffer distance: 1,500 ft)

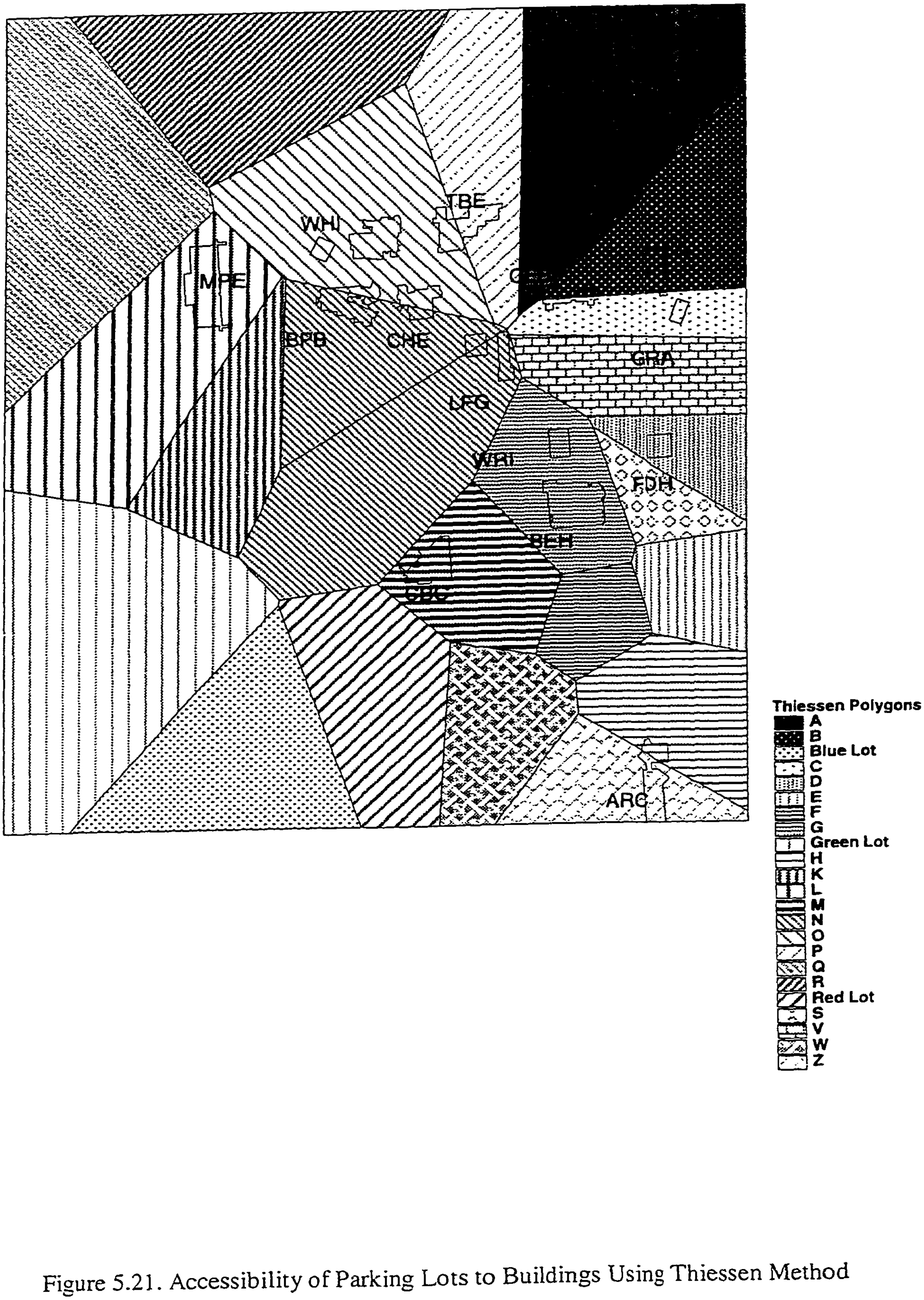


Figure 5.21. Accessibility of Parking Lots to Buildings Using Thiessen Method

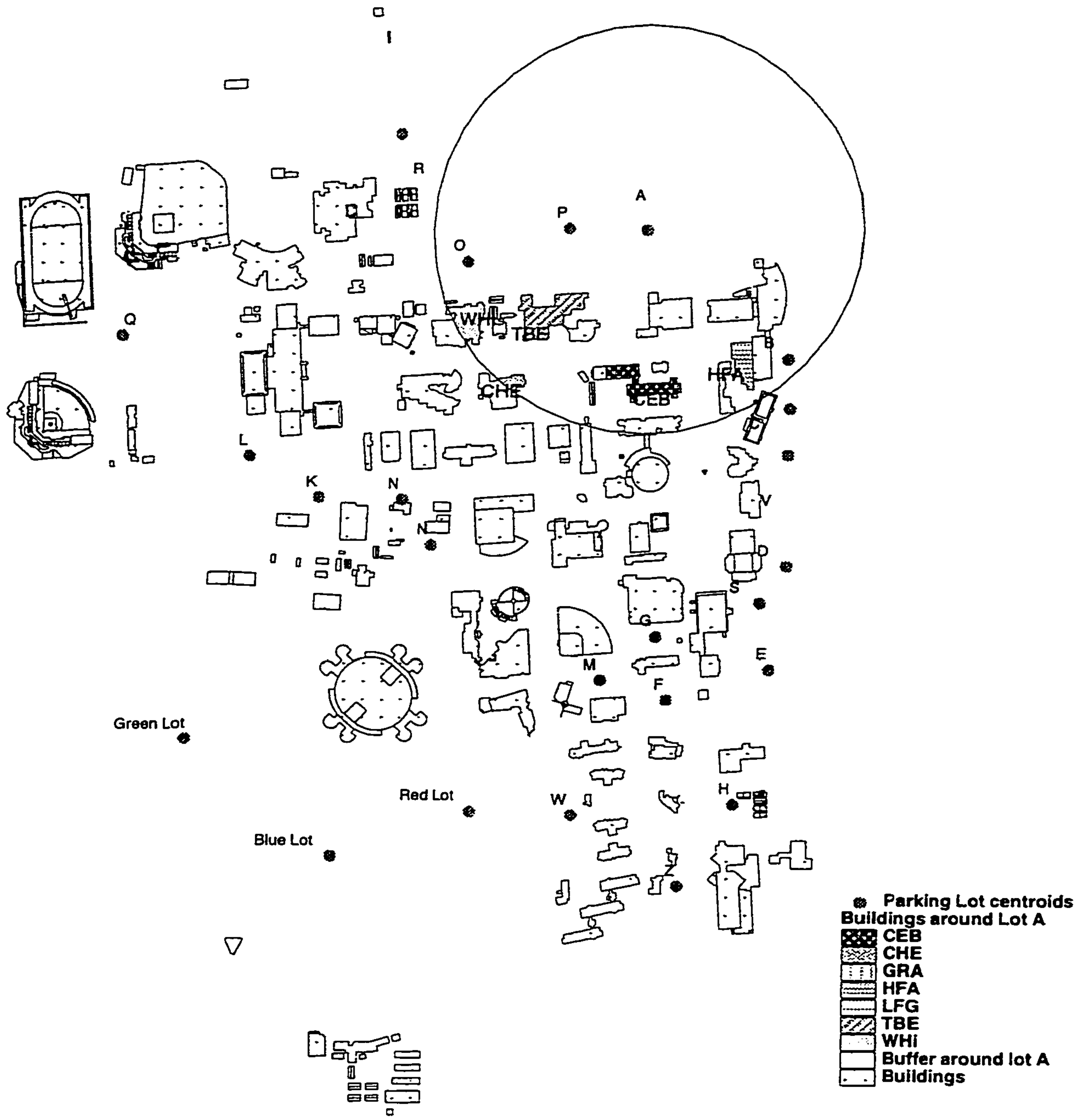


Figure 5.22. Accessibility of Parking Lot A to Buildings Using Buffer Method

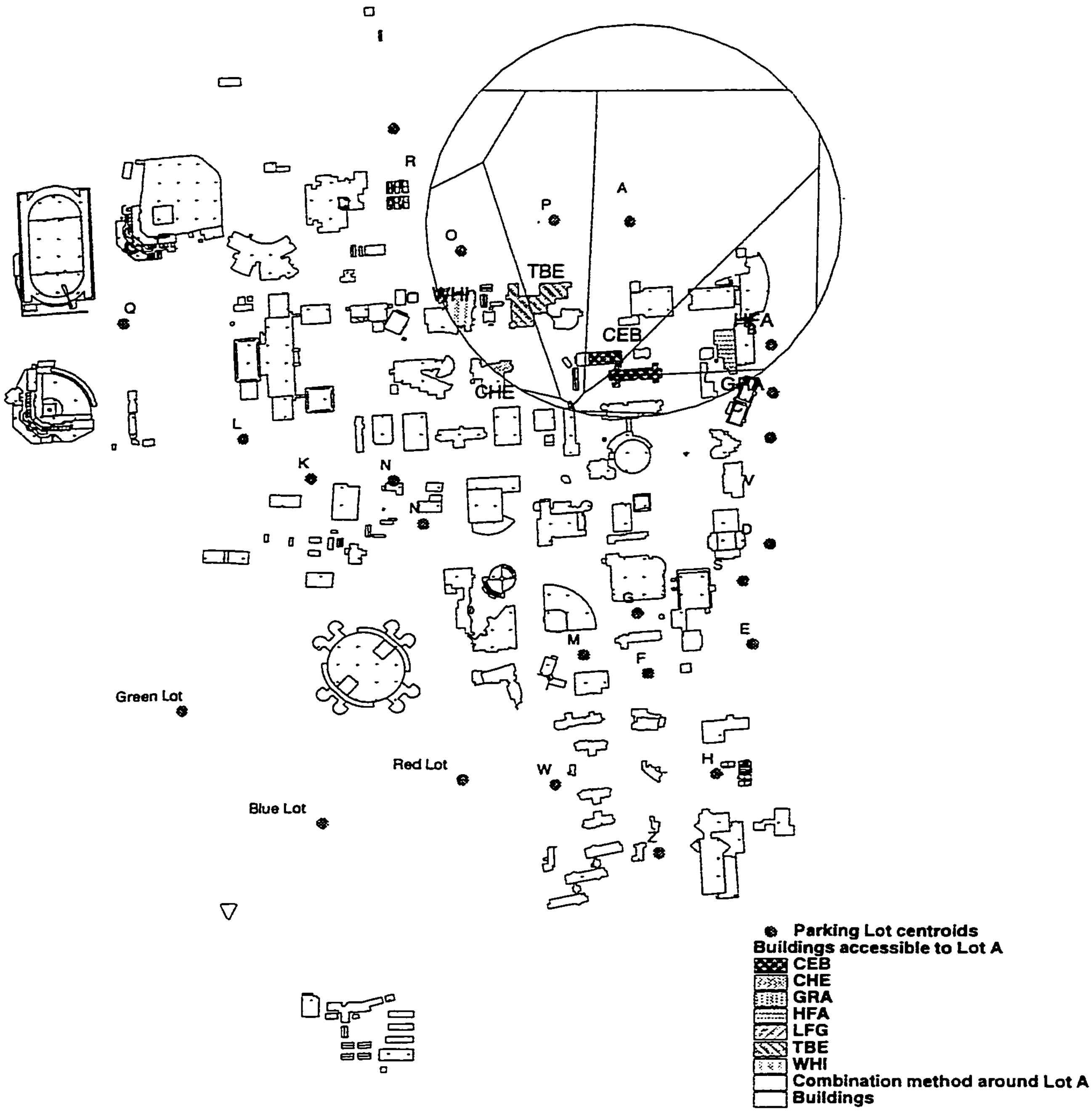


Figure 5.23. Accessibility of Parking Lot A to Buildings Using Combination Method

5.8 Graphical Representation of Utilization Measures

The utilization measures of buildings and parking lots developed are represented graphically using ArcView a GIS program. The following figures show the utilization of classrooms, stations, and parking lots respectively. Figures 5.24 to 5.29 reveal the distribution of percentage of room utilization and student station utilization of classrooms and laboratories. Figure 5.24 depicts the percentage utilization of classrooms during the whole day. Quite a number of buildings are in the 75-100 percent utilization range. Two buildings are utilized more than 100 percent. Three buildings are utilized in the range of 50-75 percent. Figure 5.25 depicts the percentage utilization of laboratories. Five buildings are in the range of 0-25 percent, and the number of buildings with more than 50 percent utilization is six. Figure 5.25 to 5.28 reveal the percentage distribution of student stations during day and evening time. Figure 5.26 depicts the percentage utilization of student stations in a classroom during daytime. The figure indicates that eight out of sixteen buildings have less than 50 percent student station utilization during daytime. Figure 5.27 indicates that ten out of sixteen buildings have less than 50 percent utilization during evening time. Two buildings have more than 100 percent utilization. Figure 5.28 indicates the percentage utilization of student stations in laboratories during daytime. The figure indicates that nine buildings have less than 50 percent station utilization during daytime and one out of sixteen buildings have a percentage of more than 80 percent. Figure 5.29 indicates the percentage utilization of student stations in laboratories during evening time. Six out of sixteen buildings are utilized less than 50 percent. Overall the percentage utilization of rooms is better than percentage utilization of stations.

Figures 5.30 to 5.39 represent the utilization of student and faculty parking lots on Weekdays. Figures 5.30 and 5.31 reveals the distribution of percentage utilization of parking lots during Monday AM and PM peak respectively. Nine out of ten student parking lots are utilized for more than 80 percent during the AM peak. The distribution during the PM peak varies significantly. Two parking lots have more than 80 percent utilization. Figures 5.32 and 5.33 represents the distribution of percentage utilization of parking lots during Tuesday AM and PM peak respectively. The results from the AM and the PM peak do not vary significantly on Tuesday. Six out of ten student parking lots are utilized for more than 80 percent. Figure 5.34 represents the distribution of percentage utilization of student parking lots on a Friday AM peak. A significant number of parking lots are utilized in the range of 60-80 percent. Two out of ten parking lots are utilized by more than 80 percent. Three parking lots are utilized with less than 40 percent utilization. Figures 5.35 to 5.39 reveals the distribution of percentage utilization of faculty parking lots on weekdays. Figure 5.35 indicates that except for one parking lot the rest of them are more than 90 percent utilized during AM peak. Figure 5.36 indicates that the percentage utilization of faculty parking lots is distributed equally. Five parking lots are utilized less than 60 percent. Figures 5.37 and 5.38 represent the percentage utilization of faculty parking lots on Tuesday AM and PM peak respectively. There is not significant difference between AM and PM peak utilization. A significant number of parking lots are utilized for more than 80 percent. Figure 5.39 represents the percentage utilization of faculty parking lot on Friday AM peak. Four out of eleven parking lots are utilized less than 80 percent. One parking lot is used with less than 20 percent utilization.

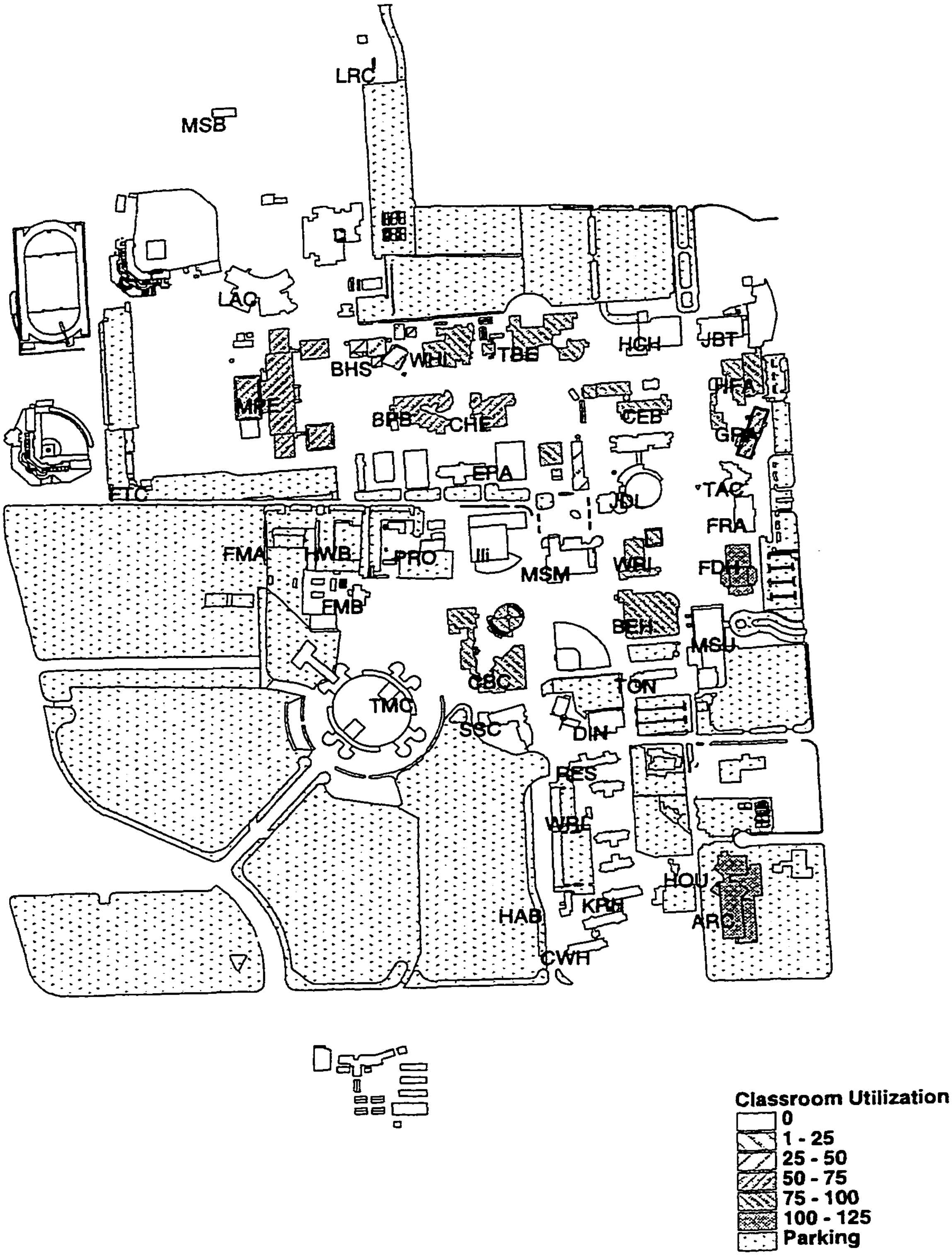


Figure 5.24. Percent Utilization of Classrooms

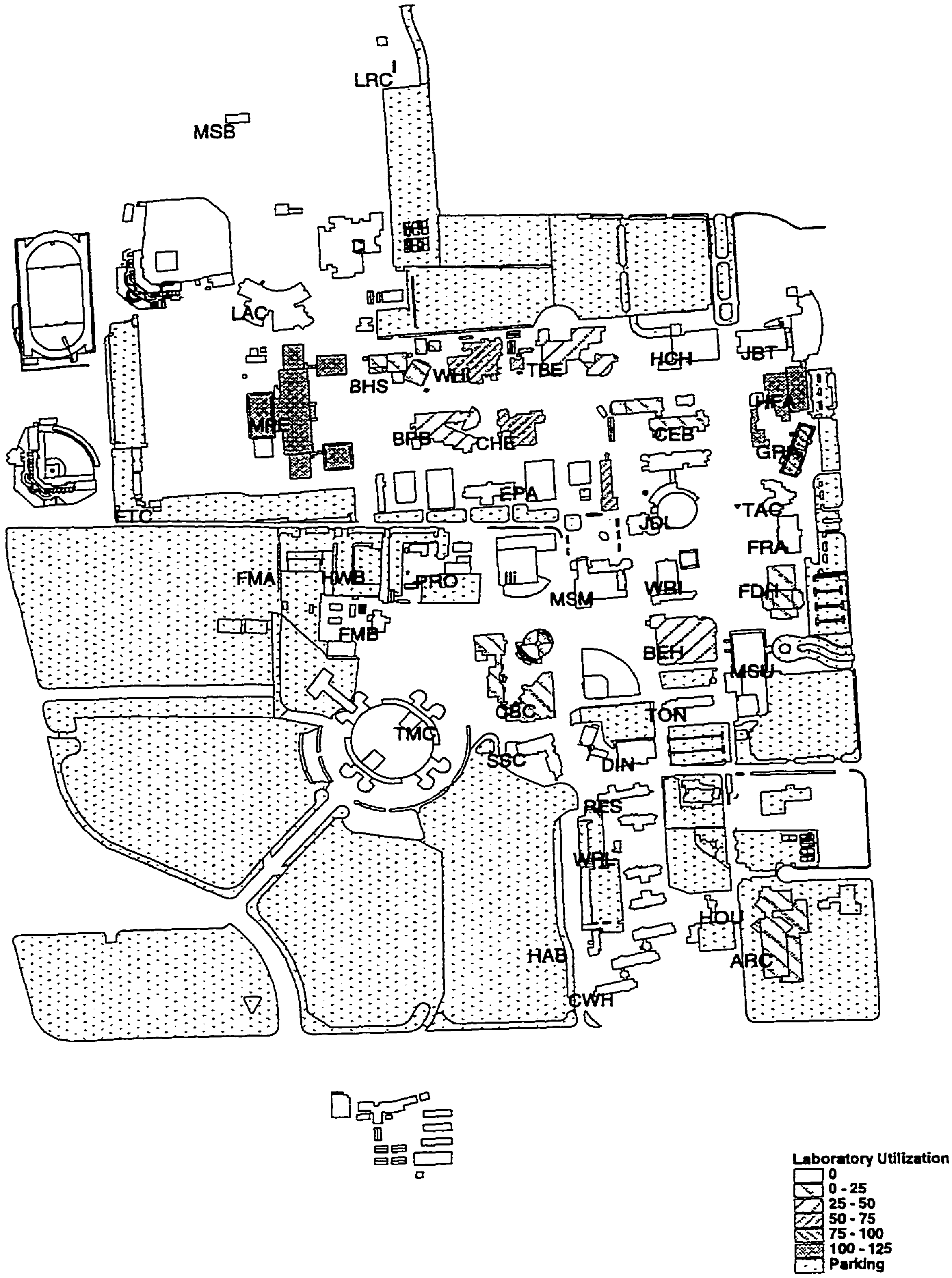


Figure 5.25. Percent Utilization of Laboratories

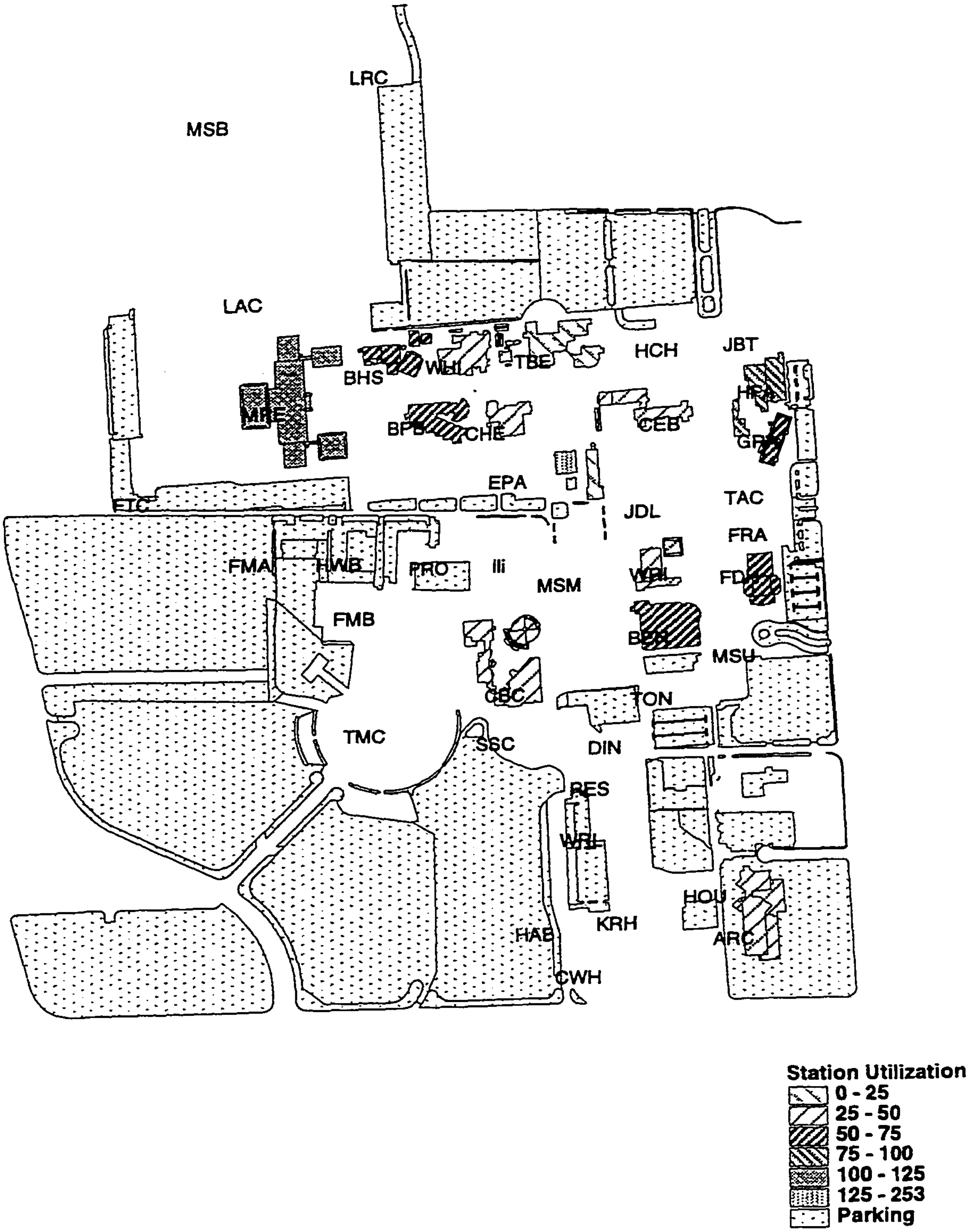


Figure 5.26. Daytime Percent Utilization of Stations in Classroom

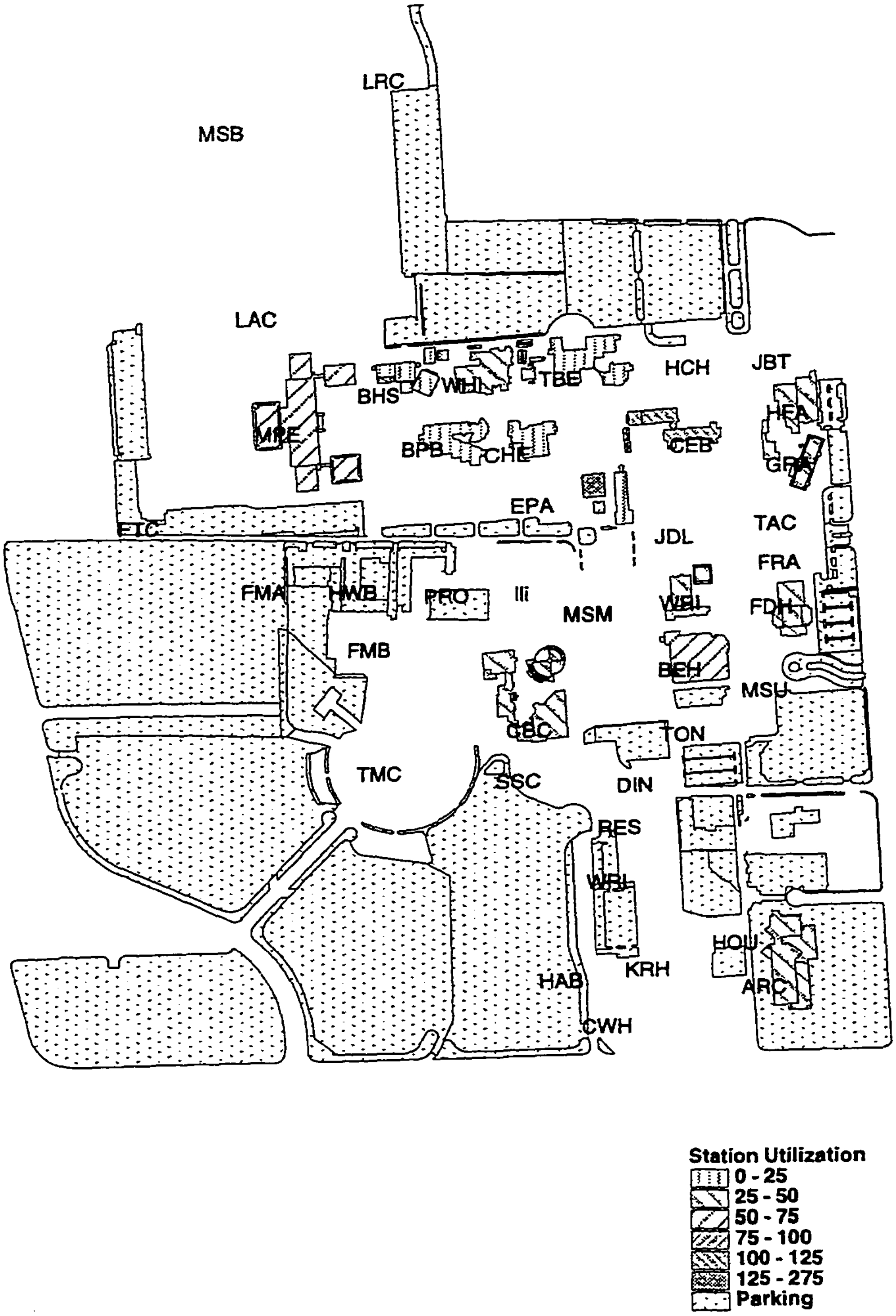


Figure 5.27. Evening time Percent Utilization of Stations in Classrooms

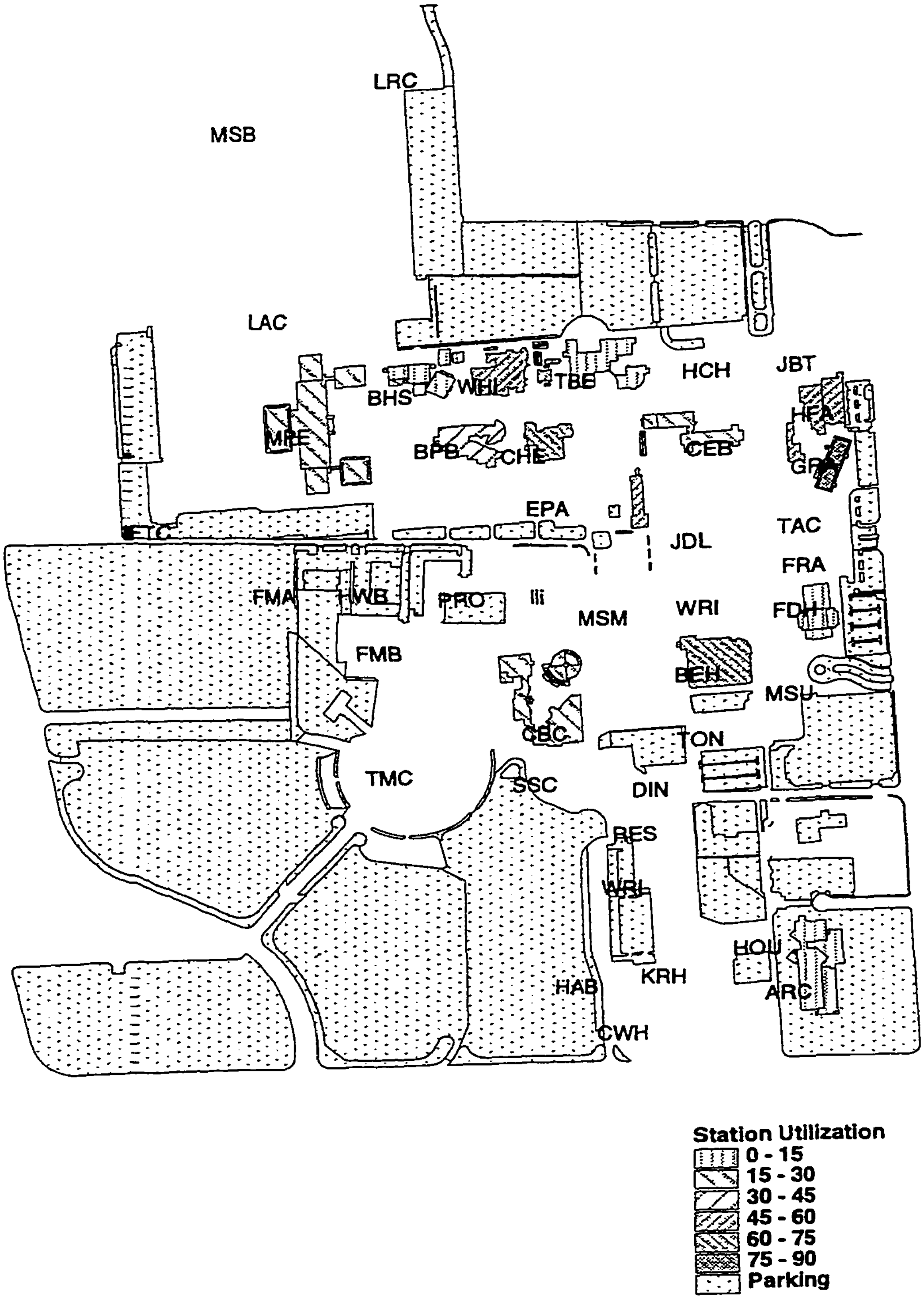


Figure 5.28. Daytime Percent Utilization of Stations in Laboratories

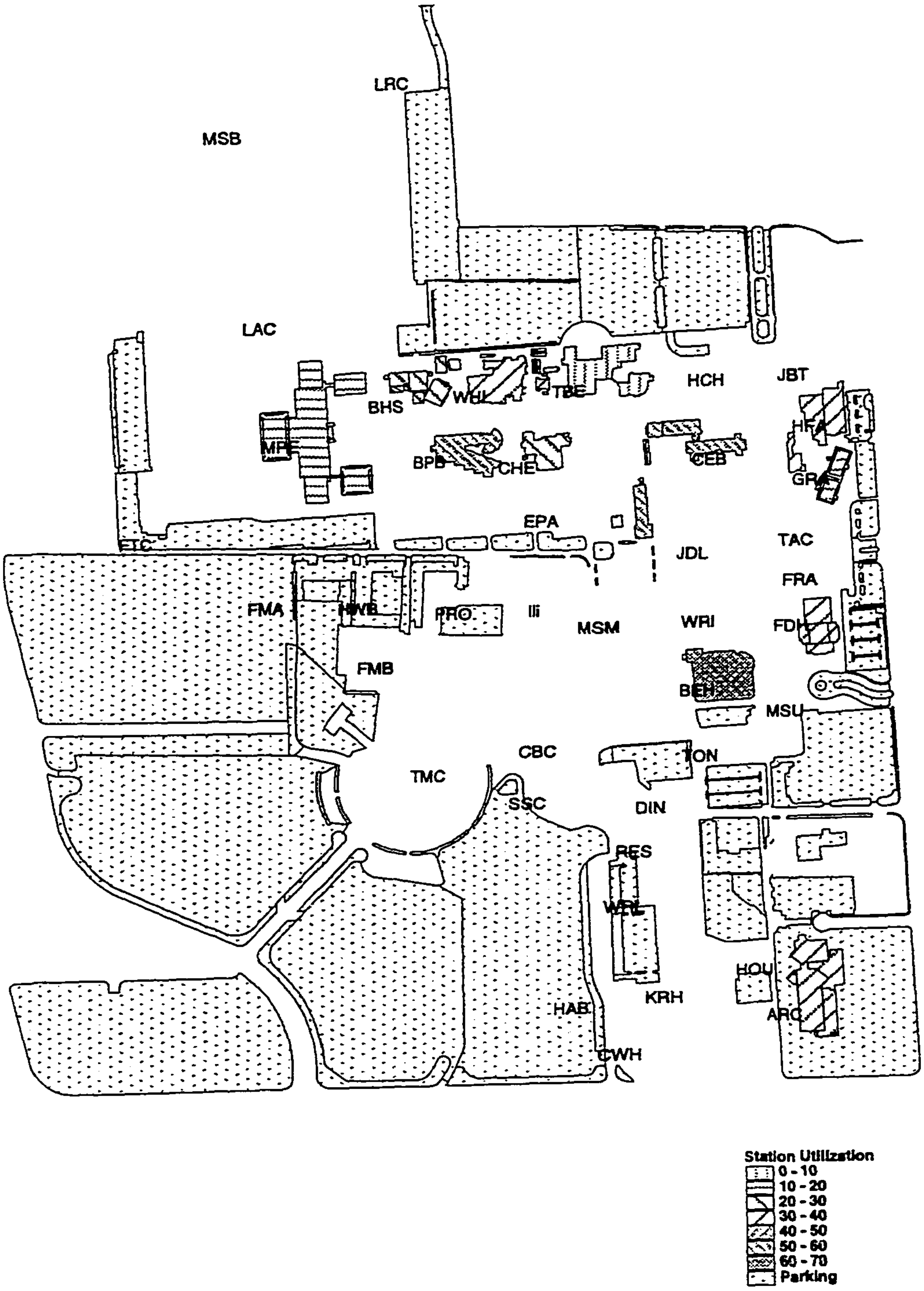


Figure 5.29. Evening time Percent Utilization of Stations in Laboratories

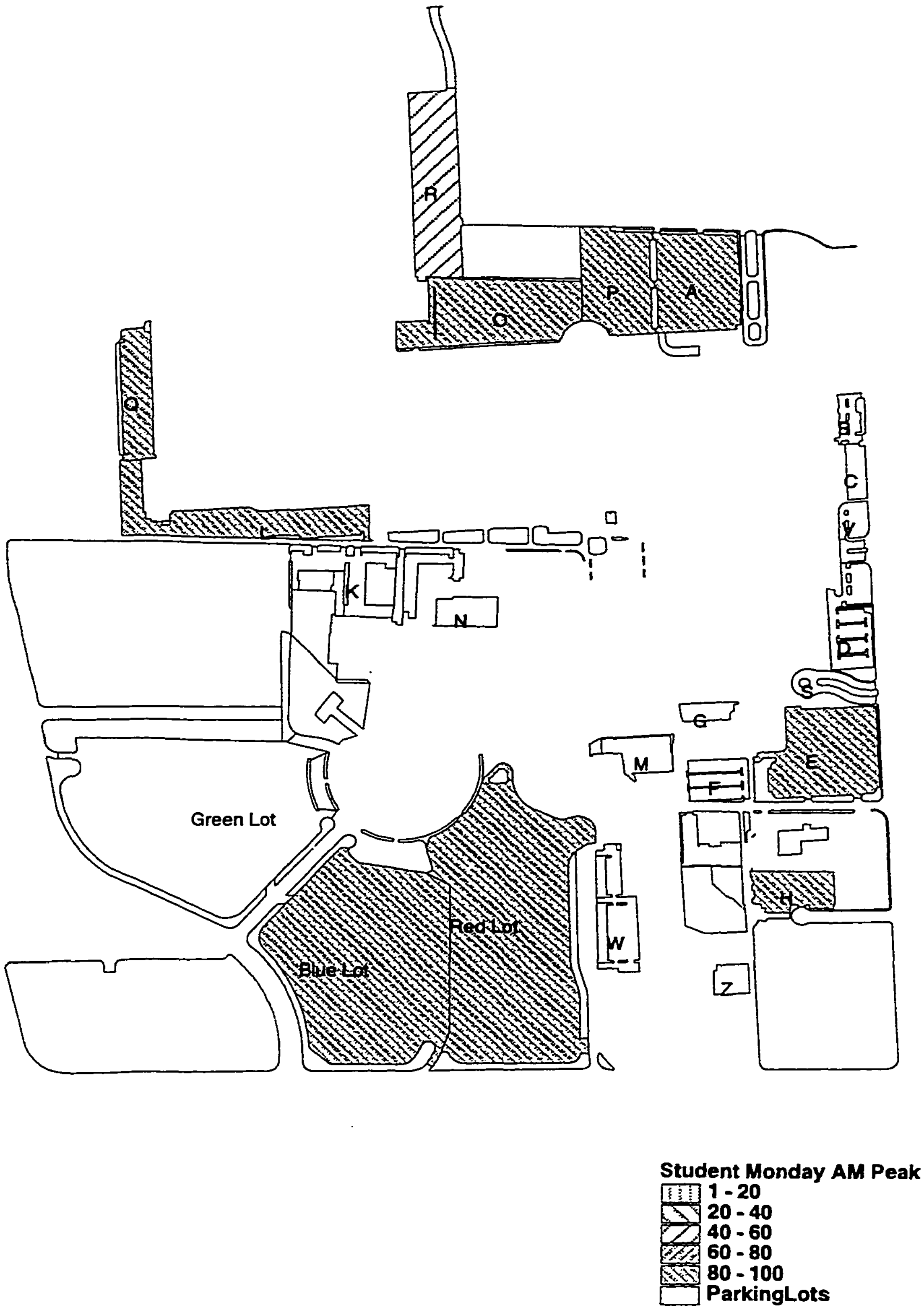


Figure 5.30. Utilization of Student Parking Lots on Mondays (AM Peak)

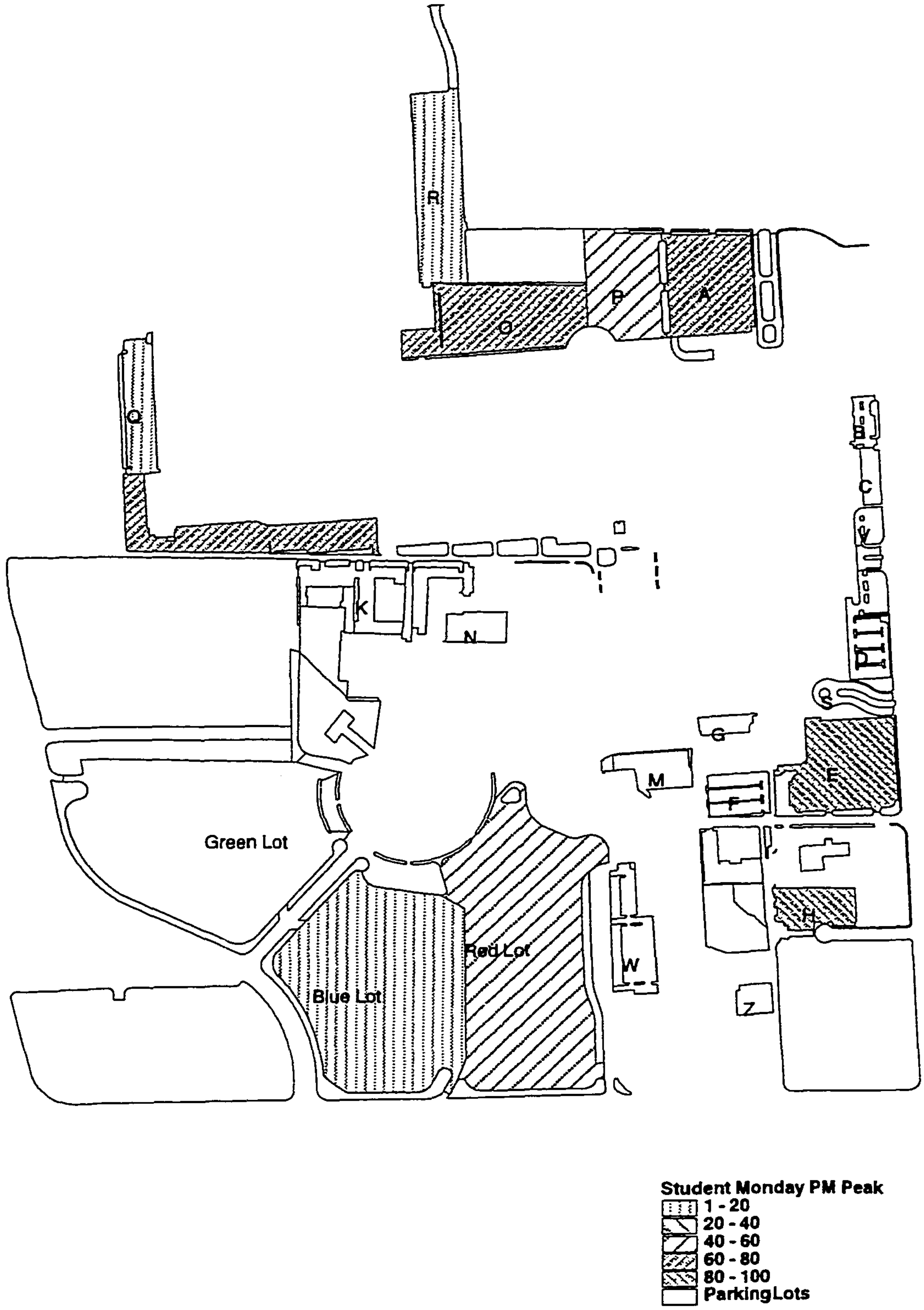


Figure 5.31. Utilization of Student Parking Lots on Mondays (PM Peak)

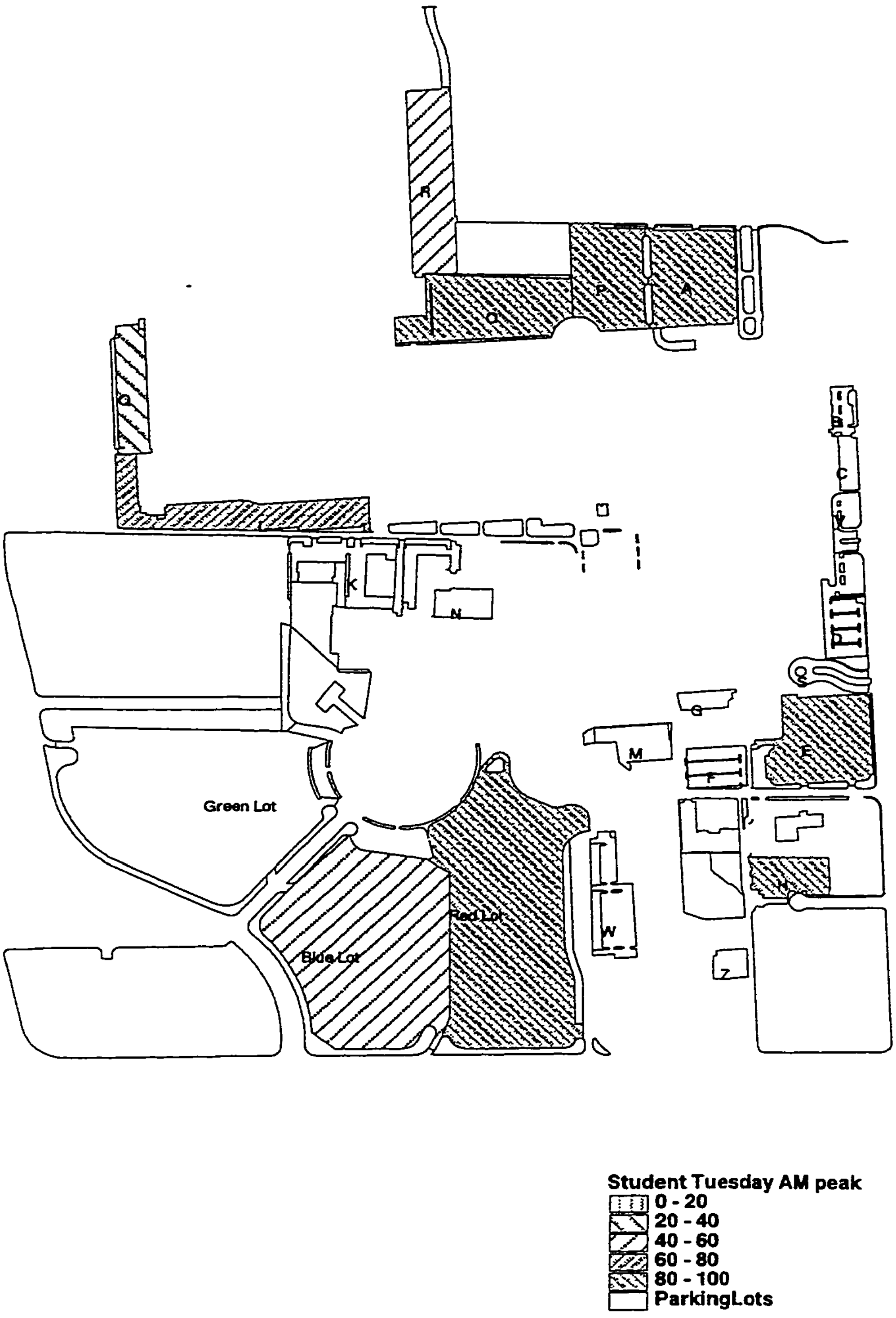


Figure 5.32. Utilization of Student Parking Lots on Tuesdays (AM Peak)

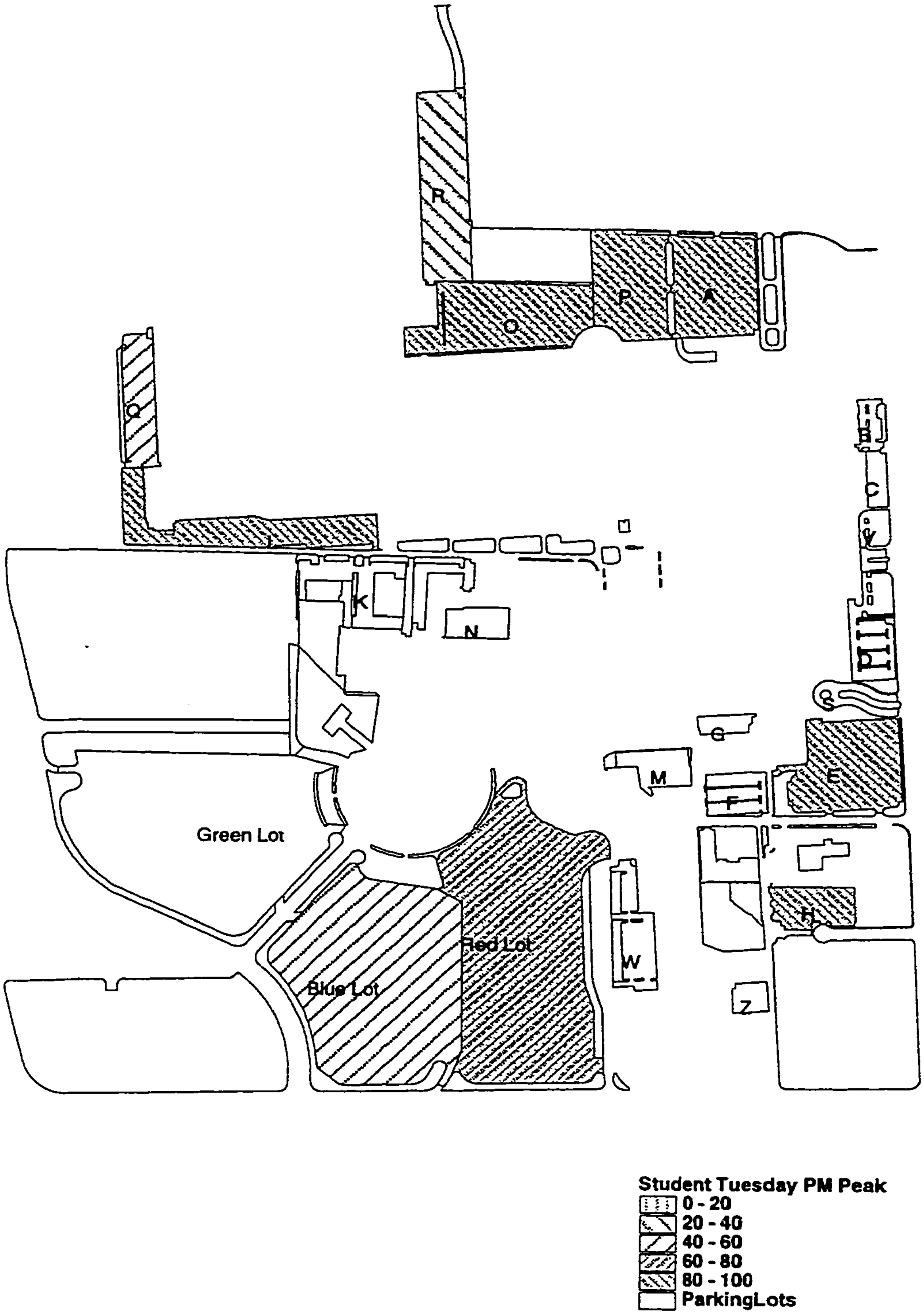


Figure 5.33. Utilization of Student Parking Lots on Tuesdays (PM Peak)

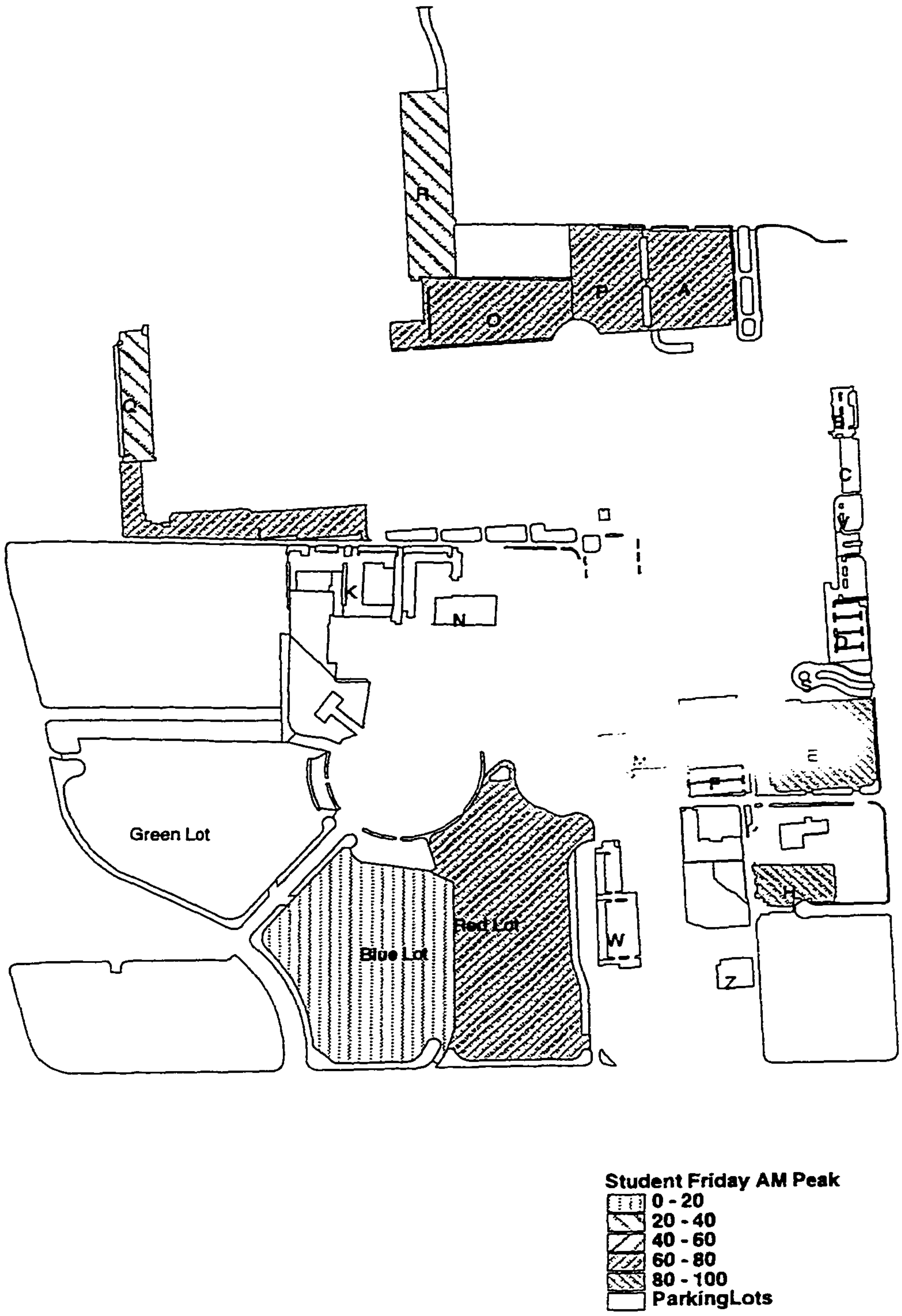


Figure 5.34. Utilization of Student Parking Lots on Fridays (AM Peak)

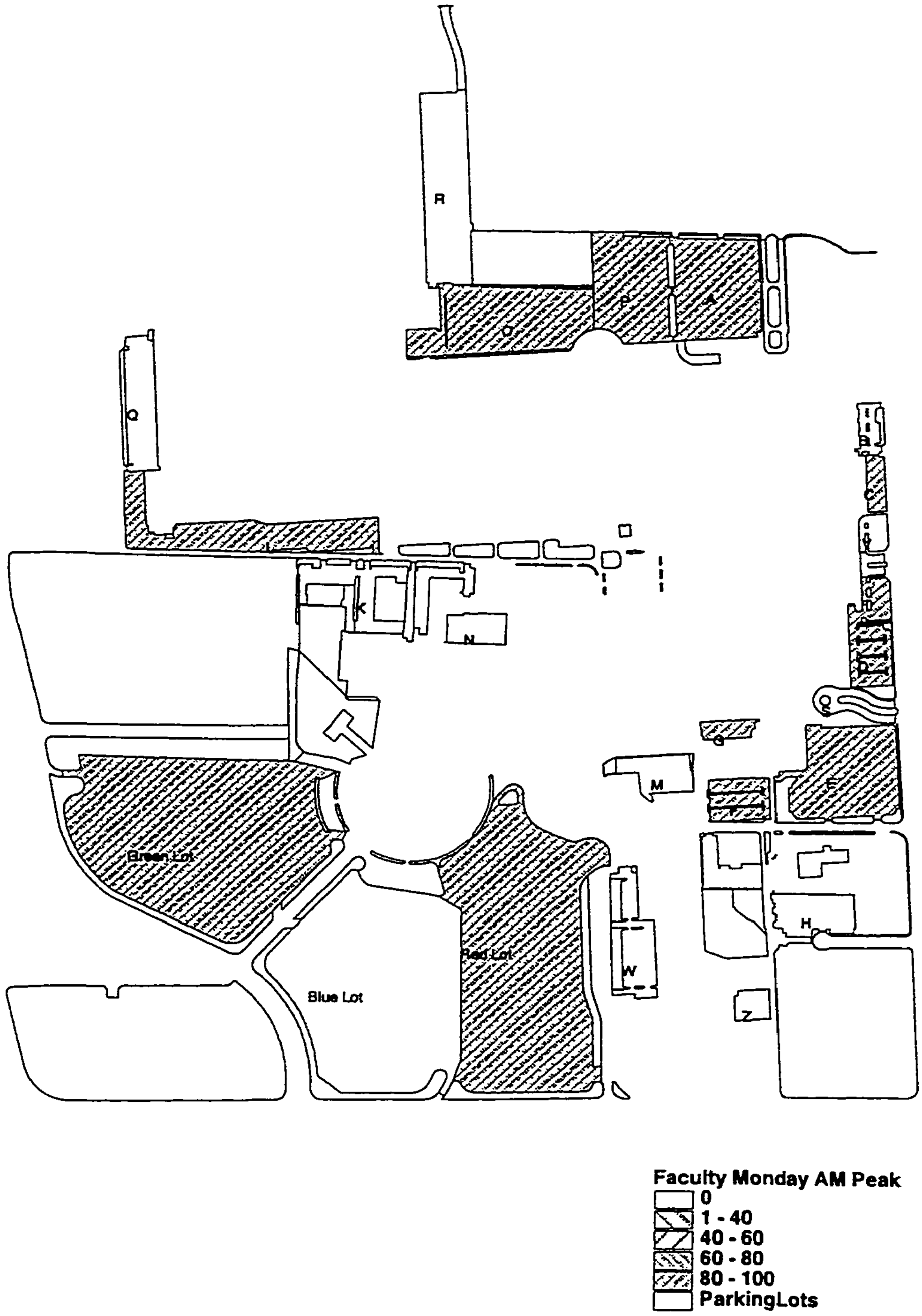


Figure 5.35. Utilization of Faculty Parking Lots on Mondays (AM Peak)

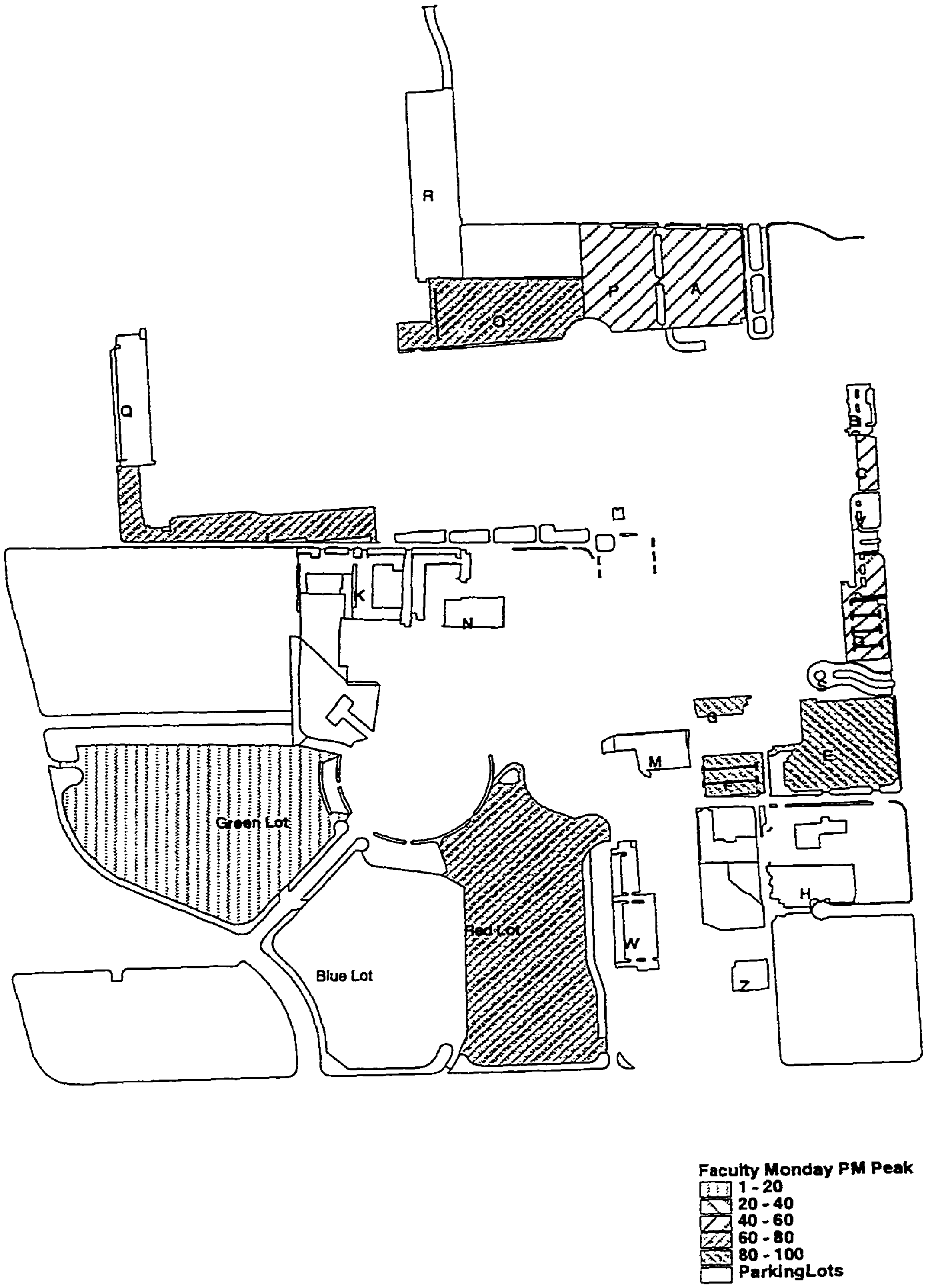


Figure 5.36. Utilization of Faculty Parking Lots on Mondays (PM Peak)

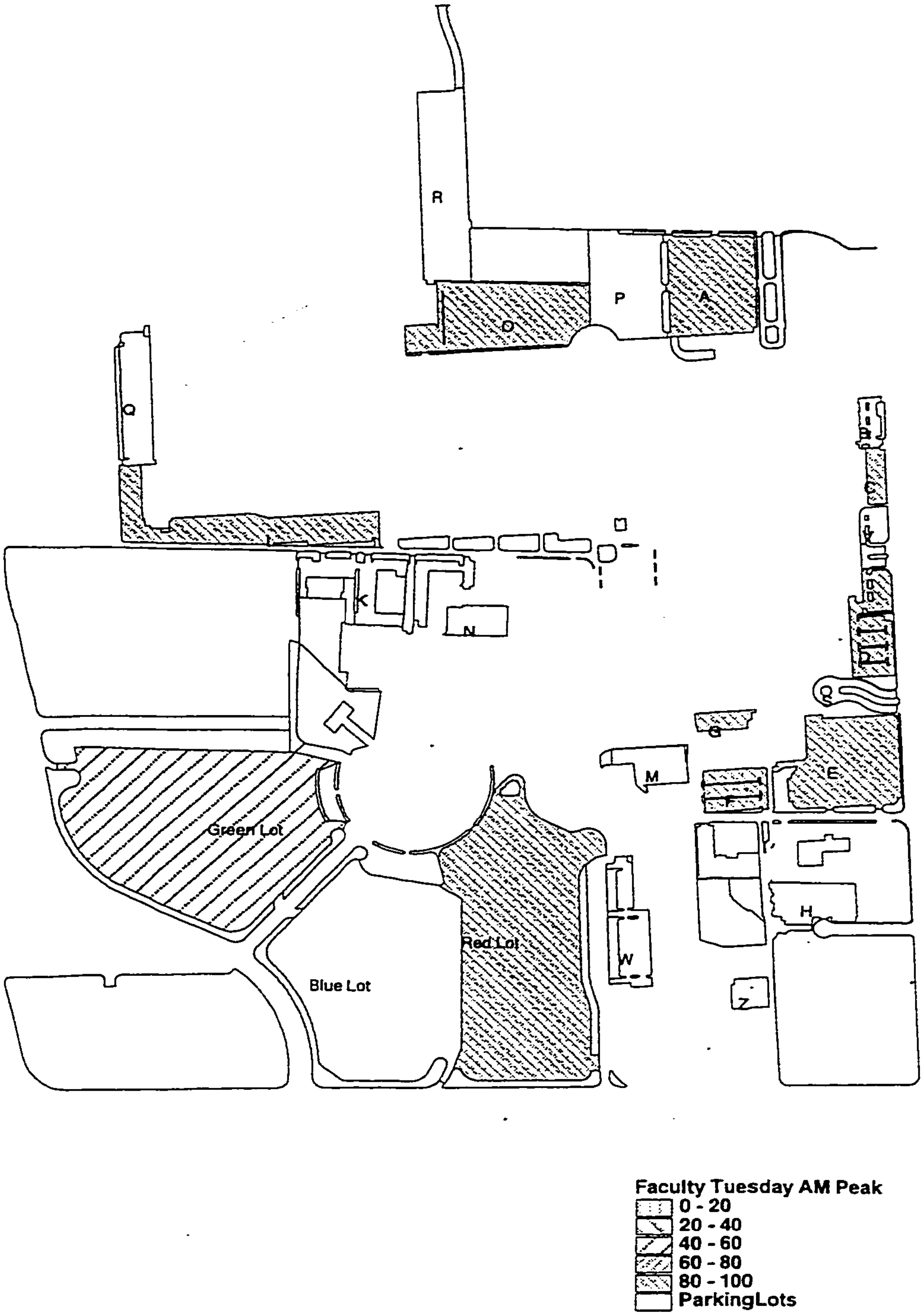


Figure 5.37. Utilization of Faculty Parking Lots on Tuesdays (AM Peak)

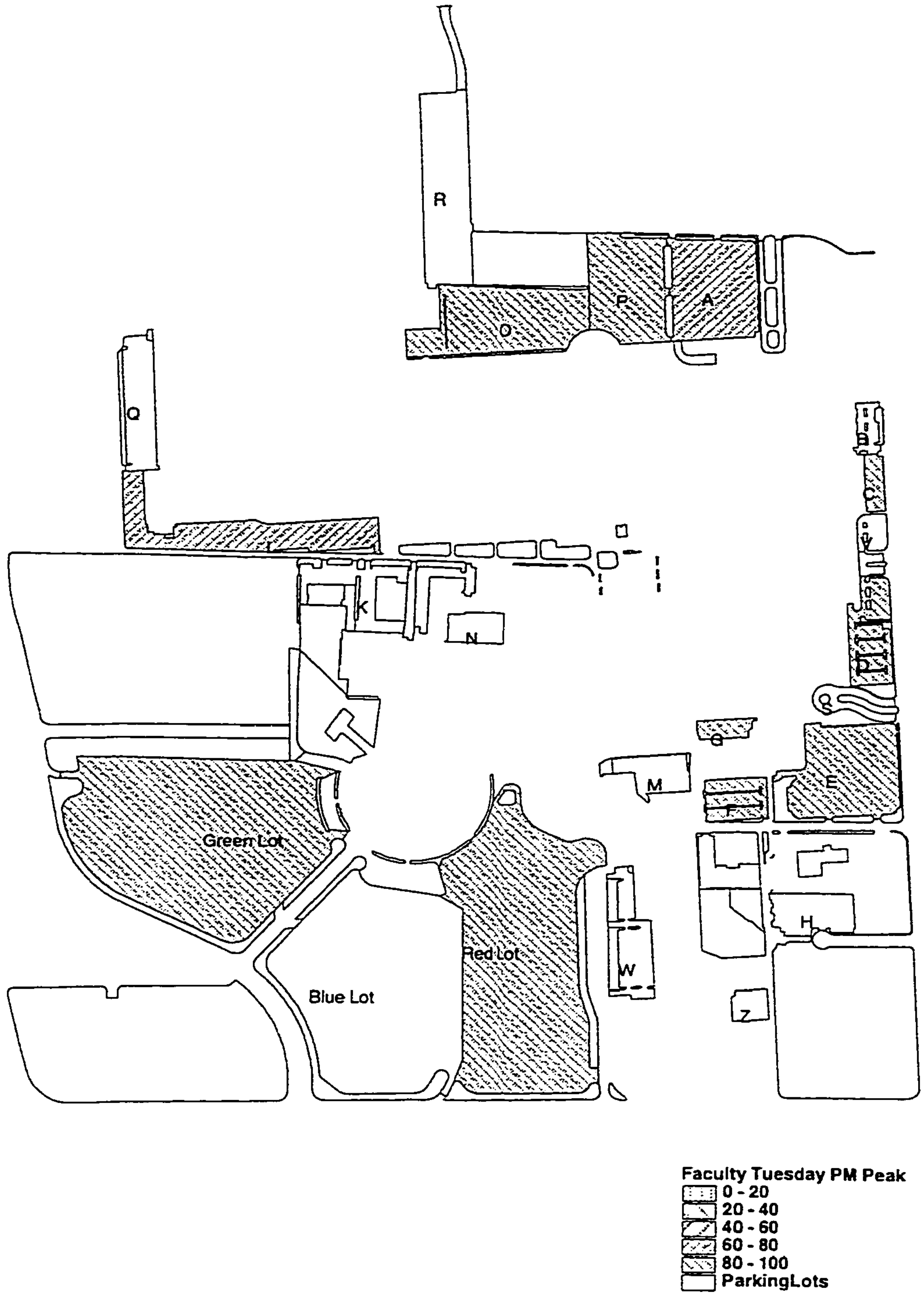


Figure 5.38. Utilization of Faculty Parking Lots on Tuesdays (PM Peak)

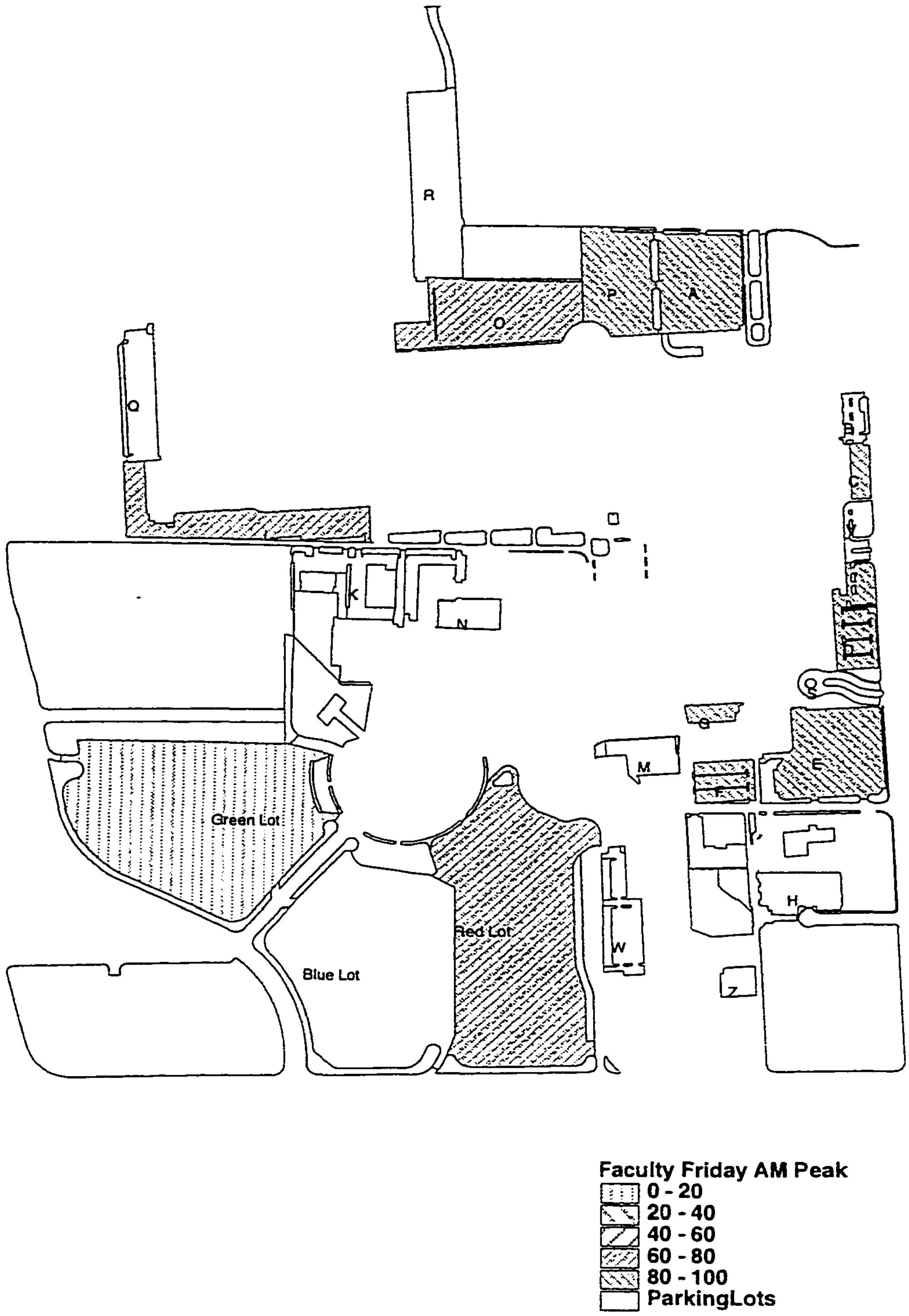


Figure 5.39. Utilization of Faculty Parking Lots on Fridays (AM Peak)

CHAPTER 6

SUMMARY AND CONCLUSIONS

This chapter contains a brief summary of work documented in this thesis. Conclusions and recommendations for further study also are presented.

6.1 Summary

Large organizations such as universities typically occupy many buildings and parking spaces. A typical university space includes classrooms, laboratories, offices and parking. The cost of adding additional space is significant. Therefore, effective management and utilization of the existing space is critical. The primary objective of this thesis was to develop a framework for analysis and evaluation of space and parking utilization and to develop a computerized tool based on the framework to support analysis and queries. A systematic approach was developed to implement the framework with the use of the available data.

In this thesis classrooms and laboratories were considered for the development of building utilization measures. The procedure developed integrates a five-step process involving ArcInfo/ArcView (a GIS program), Visual Basic, and MS Access database software programs. In particular, spatial analysis and database management capabilities make GIS a good resource for this application. The five-step process is as follows:

- To develop and quantify the utilization measures of buildings
- To quantify supply and demand and to develop utilization measures of parking lots.
- To evaluate accessibility from parking lots to buildings and vice versa.
- Representation of utilization measures and accessibility indices in color-coded maps.
- Development of a user interface to estimate the building utilization measures.

The methodology developed to quantify the utilization measures of buildings was based on three different utilization measures: utilization of classrooms/laboratory in hours, utilization of classrooms/laboratories in percentage, and student station utilization in percentage of buildings. These were defined based on daytime and evening time usage. Daytime was defined as 8:00AM to 5:00PM and evening time was defined as 5:00PM to 10:00PM. The number of buildings considered for this study was 16 out of 76 buildings on-campus. The buildings were selected based on the criteria that each either contained a classroom or a laboratory.

The methodology developed to quantify supply and demand and to develop utilization measures of parking lots was based on data collected from field surveys and in-class surveys. Six different types of usage in parking lots (student, faculty, metered, visitor, handicapped, resident) were identified. Seventeen different parking lots were considered for conducting field surveys. Field surveys were conducted at six different time periods on Monday or Wednesday, Tuesday or Thursday, and Friday to study the utilization of parking lots by type of usage. In-class surveys were conducted to determine the characteristics which affect the parking demand. Data collected included the mode of travel, parking lot used, building of first and last class of the day, and their origin/destination.

The methodology developed to evaluate accessibility from parking lots to buildings and vice-versa was based on three different approaches. The accessibility of parking lots to the building influences the utilization of parking lots and other related characteristics which effect the parking demand. The results obtained can be used to quantify building utilization and parking supply. The three different approaches that were used to develop accessibility indices are Thiessen polygon method, Buffer method, and Combination of Thiessen and Buffer method. The results from in-class surveys were compared with the results obtained from accessibility indices. Arc/Info, a GIS program was used to develop the accessibility indices and represent them graphically.

For better understanding of the utilization of the campus and scope of spatial analysis, utilization measures and accessibility indices are represented in color-coded maps using ArcView, a GIS program, in addition to tabular outputs and charts.

A user interface was developed to help estimate the building utilization measures. The main objective of developing the tool was to help support the user to perform queries and analyses related to the building utilization measures. The interface facilitates many types of analyses. Analyses were for all buildings and rooms, for all rooms in a building, and for a single room in a building by type of usage and day/evening. The development of the application is a two step process. The first was the design and construction of the database. The second step was the design and development of the front-end application. The attributes of the database include buildings, room number, stations, student enrollment, day of the week, time of the day, and class hours. The different "forms" (user interfaces) developed are as follows:

- To query the database based on building, room number, usage and time of day criteria.
- To calculate room period utilization in hours
- To calculate percentage of room period utilization.
- To calculate percentage of student station utilization.
- To query the details of all rooms and buildings based on the number of stations criteria.

6.2 Conclusions

The methodology to develop a framework for the evaluation of space and parking utilization was accomplished by developing the utilization measures of the campus and a computerized tool to support the analysis. Accessibility of parking lots to buildings were developed to quantify the building utilization and parking supply. The University of Nevada, Las Vegas (UNLV) was considered as a case study for developing the above framework and to evaluate its implementation.

It can be concluded that the utilization of classrooms at UNLV is higher than the utilization of student stations in the classrooms. That is, the rooms can be utilized more efficiently. The results obtained from parking utilization studies indicate that the AM peak utilization is higher than the PM peak utilization. This indicates that more classes could be scheduled during the evening time. Based on the results obtained, students must be encouraged to park in parking lots with low utilization. In-class survey results indicate that 87.5 percent of students drive to university while others use different modes of transportation. Hence, students must be encouraged to use other modes of transportation such as transit, walking, bicycles, and by providing incentives such as transit pass etc.

The results obtained from this thesis are useful for decision-making purposes. For example, scheduling of classes may be improved based on the room period utilization and student station utilization The research helps facilities management and planning. For example, based on the utilization measures developed, the existing buildings can be utilized more efficiently before providing new buildings or parking lots, and better utilization of the space on campus can be achieved.

6.3 Recommendations for Future Work

The work presented in this thesis allows quantitative analysis, graphical representation of utilization measures, development of accessibility indices and development of a user interface for developing utilization measures. These models help mostly at a macroscopic level. The developed tools can be used at a microscopic level. They are as follows:

- The research effort presented was to develop the utilization measures of classrooms and laboratories; the same tool can be extended to develop utilization measures for other types of rooms such as offices, conference rooms, student lounges, cafeterias, etc.

- In this thesis, parking lots were color-coded as a whole but not based on the type of usage (student, faculty, metered, handicapped, resident, visitors)- i.e., the total area of the parking lot was considered based on the parking utilization measures. Instead, the parking lot can be color-coded by dividing the lot into different sub lots based on usage. For example, if the student spaces are 70 percent utilized and faculty parking spaces are 80 percent utilized, they can be color-coded differently based on the utilization within the same lot.
- Accessibility indices were developed using the whole area of the parking lot. For microscopic analysis, the parking lot coverage can be divided into different sub-lots based on type of usage (student, faculty, metered, handicapped, resident, visitors) and accessibility indices developed separately for each sub lot.
- Another important tool developed was the user interface. The user interface was developed for constructing utilization measures of the buildings. The same model can be implemented to develop parking utilization measures of the campus.
- This research can be expanded for other types of facilities and infrastructure management. Some of the issues that can be addressed are development of a tool for implementing smart buildings, tools that help in finding energy consumption, etc.

Appendix A

Building Codes and Names

ARC	Paul B.Sogg Architecture
BEH	Frank and Estella Beam Hall
BHS	Rod Lee Bigelow Physics
BPB	Robert L. Bigelow Physics
CBC	Classroom Building Complex
CEB	William D. Carlson Education
CHE	Chemistry
FDH	Flora Dungan Humanities
GRA	Archie C. Grant Hall
HFA	Alta Ham Fine Arts
LFG	Lilly Fong Geoscience
MPE	Paul C. McDermott Physical Education
TBE	Thomas T.Beam Engineering Complex
TEC	Technology
WHI	Juanita Greer White Life Science
WRI	John S. Wright Hall

Appendix B

Notations Used in this Thesis

a_{ji} Area of the buffered zone j in polygon i

A_i Accessibility of the node i

A_i Area of the polygon i

A_j Balancing factor for demand location j

A_{ij} Accessibility of j with respect to i

c_{ij} Distance between demand location j and site i

$C_{C.D}$ Average classroom utilization in a building during daytime

$C_{C.E}$ Average classroom utilization in a building during Evening time

$C_{L.D}$ Average laboratory utilization in a building during daytime

$C_{L.E}$ Average laboratory utilization in a building during Evening time

B_D Average building utilization during daytime

B_E Average building utilization during Evening time

CH_i Number of scheduled class hours in classroom i in a building

DCH_i Number of scheduled class hours in classroom i during daytime in a given building

DLH_j Number of scheduled laboratory hours in laboratory j during daytime in a given building

ECH_i Number of scheduled class hours in classroom i during evening time in a building

ELH_j Number of scheduled laboratory hours in laboratory j during evening time in a given building

d_{ij} Measure of impedance between i and j

D_j Demand at location j

$F(c_{ij})$ Function of distance between i and j

GDP_j Gross Domestic Property of the destination economic activity center j

i=1..n Number of classrooms

i=1..m Number of laboratories

i=1..p Number of parking type

I_{ij} Real impedance between nodes i and j

j Parking lot

k Total number of class hours

k=1..x Number of class periods

LH Number of scheduled laboratory hours in a building

n Number of scheduled classrooms in a building

N_i Number of parking spaces in polygon i

m Number of scheduled laboratories in a building

O_i Estimated turnover in site i

$P_{C.B}$ Percentage of classroom utilization C in a building B

$P_{L.B}$ Percentage of Laboratory utilization L in a building B

P_B Percentage utilization of a building B

P_{ij} Total number of parking spaces available in lot j for parking type i

PO_{ij} Number of parking spaces of type i occupied in lot j

PU_{ij} Parking utilization of type i in parking lot j

r_i Number of parking spaces in the buffered zone j

$S_{C.D}$ Student station utilization of a classroom i during day-time.

$S_{C.E}$ Student station utilization of a classroom i during evening-time.

$S_{L.D}$ Student station utilization of a laboratory j during day-time.

$S_{L.E}$ Student station utilization of a laboratory j during evening-time.

$S_{B.D}$ Student station utilization of a building during day-time.

$S_{B.E}$ Student station utilization of a building during evening-time.

S_i Number of stations in classroom i

S_j Number of stations in laboratory j

$SE_{i,k}$ Number of students enrolled during a class period k in a classroom i

$SE_{j,k}$ Number of students enrolled during a class period k in a laboratory j

T_{ij} Estimated trips between demand location j and site i

TPU_j Total parking utilization in parking lot j

W_i Attraction value for site i

W_j Index of attraction of j

Bibliography

Arizona Board of Regents (1997). "Space Utilization"
www.abor.asu.edu/1_the_regents/reports_factbook/reports_factbook.html

Arwyn Jones (1999). " Use of spatial analysis to assess European transport policies." *www.esri.com/library/userconf/proc99/proce/p789.htm. pp. 1-15.*

BRW Inc (1996). "Transportation System analysis: University of Oregon"
http://darkwing.uoregon.edu ~uplan/transpo/BRWreport.html#anchor1510148

Eck, van Ritsema, J. R. (1990). "Analysis of parking problems. An application of networks". *Proceedings of the first European GIS conference (EGIS), pp.920-928. Utrecht: EGIS*

Eck, van Ritsema, J. R. and de Jong T. (1999). " Accessibility analysis and spatial competition effects in the context of GIS-supported service location planning." *Computers, Environment and Urban Systems, Vol. 23, pp.75-89*

Environmental Systems Research Institute (ESRI).(1993a) "Understanding GIS, The ARC/INFO method." *Longman Scientific and Technical.*

Environmental Systems Research Institutes (ESRI) "Understanding GIS, The ARC/INFO method" *online help manual. ArcDoc Version 7.2.1.*

Gold C. M. (1991) "Problems with handling spatial data-the Voronoi approach." *Canadian Institute of Surveying and Mapping (CISM) Journal 45: pp. 65-80.*

Gondeck-Becker, Debra (1999). "Implementing an Enterprise-Wide Space Management System - A Case Study at the University of Minnesota". *Jordan Consulting Group. www.esri.com/library/userconf/proc99/proceed/papers/pap532/p532.htm.*

Holme, Tonje and Asplan Viak Stavanger (1997). "Using GIS in Mobility and AccessibilityAnalysis". *www.esri.com/library/userconf/proc97/proc97/abstract/a440.htm.*

Ingram D. R (1971). "The concept of Accessibility: a Search for an Operational Form." *Regional Studies. Vol. 5, pp. 101-107.*

Jiang. B, C. Claramunt and B. Batty (1999). "Geometric accessibility and geographic information: extending desktop GIS to space syntax." *Computers, Environment and Urban Systems, Vol 23, pp. 127-146.*

National Center for Education Statistics (NCES). (1992) "Post secondary Education Facilities Inventory and Classification Manual." US Department of Education, Washington, DC.

NCSU "Physical Resources". North Carolina State University, Raleigh, NC *www.ncsu.edu/ncsu/univ_eval/ch12/a12adpro_p4.html*

Okabe A., Boots B. and Sugihara K., (1992) "Nearest Neighborhood Operations with Generalized Voronoi Diagrams: A Review", *International Journal of Geographical Information Systems, Vol. 8, No. 1, pp.43-71*

PAIR (1998). "Planning, Assessment, Institutional Research (PAIR)" *www.unlv.edu/PAIR/Factbook/index.html* (1998).

Parentala, Emelinda M. and Shashi S. Nambisan (2000) "Emergency Response and Disaster Management Using GIS." *Application of GIS*, American Society of Civil Engineers Monograph: pp. 181-196, Washington, D.C.

Puebla, Javier Gutierrez and Rafawl E.Gonzalez Aguayo (1995). "Transport in Europe: A StudyofTrainAccessibilityUsingGIS". *www.esri.com/library/userconf/proc95/to100/p097.html pp. 1-10*

Pulugurtha ,Srinivas S, Shashi S. Nambisan, and Nanda Srinivasan (1999). "Evaluating Transit Market Potential and Selecting locations of Transit Service Facilities Using GIS". *Journal of Public Transportation Vol. 2, No.4, pp. 75-94*

Robinson, Roger (1977). "Accessibility". Ways to Move: The geography of networks and accessibility. pp. 65-89. Cambridge University Press, London.

Russell, Dale John and James I. Doi (1957). "Definitions of terms". Manual for studies of space utilization in Colleges and Universities. *pp. 17-20. American Association of collegiate Registrars and Admissions Ofiicers, Athens, Ohio.*

Sathisan, K. Shashi and Nanda Srinivasan (1998). "Evaluation of Accessibility of Urban Transportation Networks." *Transportation Research record # 1617,* Transportation Research Board. Washington, D.C. pp. 78-83

Siler, Brain and Spotts Jeff (1998). "Using Visual Basic 6.0". *QUE publications.* September 1998.

Thiessen, A.H.and Alter J.C., (1911). "Climatological Data for July, 1911: District No. 10, great Basin." *Monthly Weather Review,* July 1911:1082-1089.

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