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Bicycle parking demand and placement facilities at Iowa State University

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by

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CHAPTER I. INTRODUCTION

The Problem

The ever increasing popularity of bicycling as a means of commuting as well as a means of recreation has been the cause of some severe traffic problems. The figures listed by R. C. Podolske in his presentation "Investing in Urban Bicycle Facilities . . . " in the Bicycles USA conference proceedings of the U.S. Department of Transportation, indicate most recently a bicycle sales growth rate of 54% per year. Since the bicycle is a relatively economical means of transportation, it is especially suited to the needs of the college student. Because of this, universities and colleges are being overwhelmed with bicycle traffic. The situation on the campus of Iowa State University is no different. This problem can be observed on any class day for which the weather is reasonably mild. Approximately 21,000 students are enrolled at the university and an additional 5,000 faculty and staff personnel are employed.

Bicycle parking regulations at Iowa State University strictly prohibit the parking of bicycles at any location not within or immediately adjacent to a bicycle rack. Any illegally parked bike is subject to impoundment.

As is evident from the multitudes of illegally parked bicycles throughout the campus, the parking regulations are rarely enforced. Violations of parking regulations may indicate a disregard for restrictions imposed on cyclists. However, concentrations of violations may also indicate a need for increased facilities to satisfy user needs.

Problem causation

Unlike the automobile, a bicycle's physical nature is such that it can be used on virtually any reasonably level, hard surface where walking is possible. This allows for an infinite number of conflict points between cyclist and pedestrian unless some form of regulation exists. Since the physical nature of the bicycle allows for the relative ease of breaking regulations, the regulations must be strictly enforceable to be effective.

The problem is complex. Cyclists need to park their bicycles near the destination for quick and efficient transportation. On the other hand, all involved desire reduced conflicts for safety considerations, and reduced clutter for aesthetic purposes. Ideally the solution would allow maximum individual freedom and mobility in the use and parking of bicycles, without hampering the safety, convenience, and aesthetic appreciation of the general public. This compromise is easy to state in general terms, but difficult to define in practice.

The bicycle system at Iowa State University

The system of bicycle paths on the Iowa State University campus consists of routes on every major street on campus as well as some additional access routes. A map depicting the bike routes is shown on page 4, Figure 1. The central part of campus, bounded by Osborn Drive on the north, Knoll Road on the east, Morrill Road on the west, and Union Drive on the south is also bounded by bicycle routes on these streets, forming an access loop for the campus. Motor vehicle traffic is restricted within the central areas during class hours by automatic gates which can be activated by authorized users with special cards or activators. The number of bicycles operated by students and staff at Iowa State University is estimated at 10,000. The number of bicycle parking spaces provided on campus in classroom areas has increased by approximately 30% since 1975.

The design of the campus bikeway system does not allow for direct travel across the central part of campus by bicycle. Current bike parking facilities near Ross Hall and Curtiss Hall, for example, are positioned apparently under the assumption that the circuitous route around the central portion of campus is followed by cyclists. However, the multitudes of bikes parked on the west side of these buildings imply that the route taken is directly from the west, and not along the specified bicycle route. These bicycles represent violations

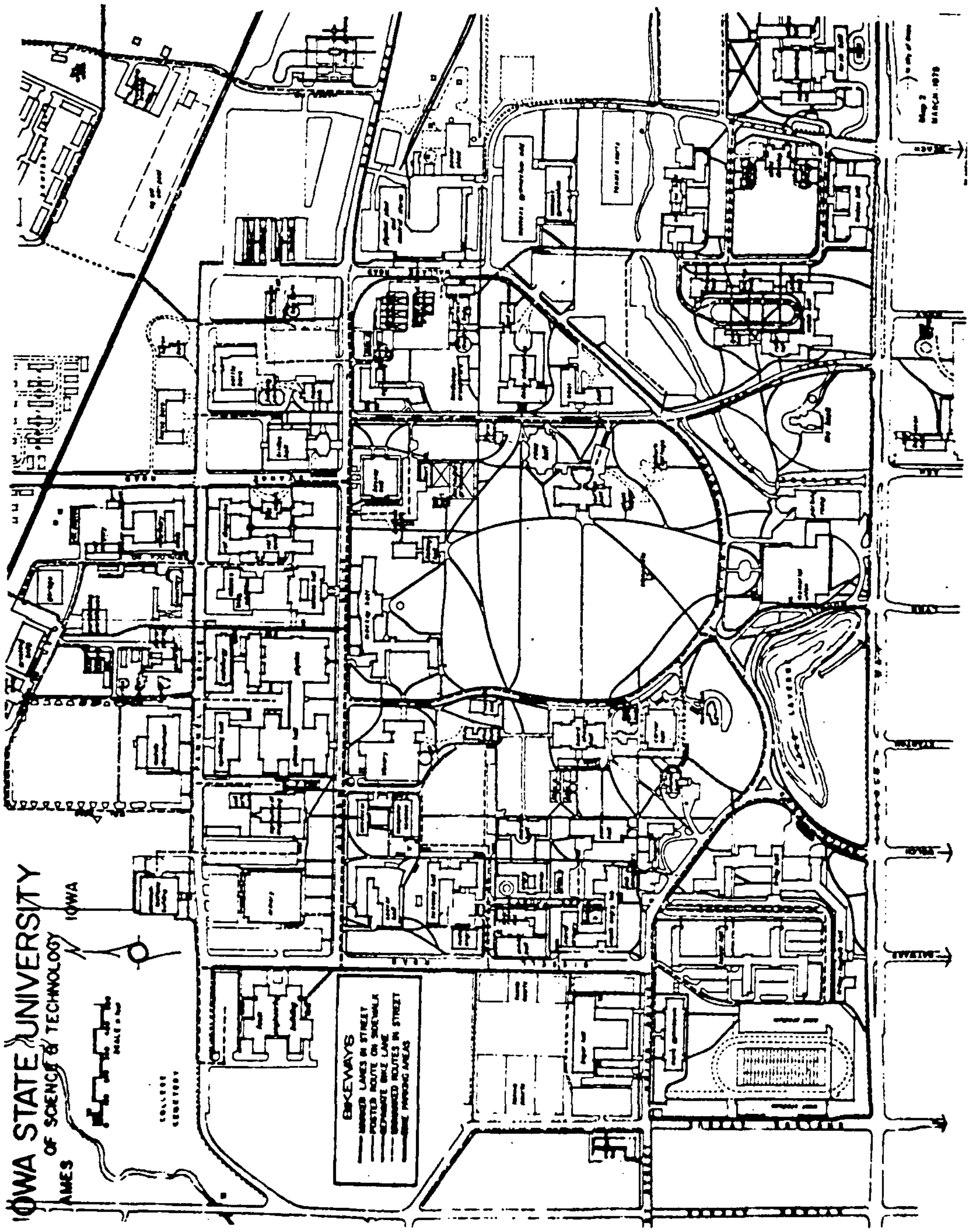


Figure 1. Map of Iowa State University bikeway system

in movement unless they were walked along the sidewalks. This is doubtful, as on any spring or fall class day one can observe bicycles being ridden on sidewalks across campus. The bicycles west of Ross and Curtiss Halls also represent violations in parking.

Since Iowa State University is considered to be a walking campus, these violations may show a need for enforcement of cycling regulations. The violations may likewise indicate a need for additional parking facilities to relieve the clutter and reduce the safety hazard around the buildings.

Students, and other individuals affiliated with a moderately sized university such as Iowa State, need a quick and efficient means of transportation. The bicycle provides that means. To regulate bicycles to the same extent as automobiles in both movement and parking would surely destroy that efficiency.

Logically, bicycles should not be allowed wherever they are a threat to the well being of pedestrians. However, to prohibit their use and parking in areas where there is no such danger would not satisfy the cyclist's needs. Where parking is concerned, the bicycle's mobility dictates that adequate facilities be located as nearly as feasible to the destination. Anything less will result in dissatisfaction, and therefore, disuse by the cyclists.

Based on an analysis of the bicycle parking activity on the Iowa State University campus during the fall quarter of 1976, recommendations will be made to possibly alleviate this problem. The recommendations will mainly be concerned with satisfying the parking demand with adequate racks at proper locations.

CHAPTER II. LITERATURE REVIEW

There is extensive literature available on the design of bikeways in general. The sources range from clubs for bicycle enthusiasts to technical journals. The proceedings of the 1973 conference of the U.S. Department of Transportation entitled Bicycles USA (22) covers several facets of bicycling. The first section deals with emerging issues in the area of cycling such as recreation, urban travel, and health. The second section deals with safety and environmental concerns. This section includes the development of federal standards for bicycle design. The third section is concerned with bikeway planning for both transportation and recreational purposes. This section includes a presentation by John Baerwald, Professor of Transportation and Traffic Engineering at the University of Illinois. He emphatically states that bike parking lots should be well integrated with the bikeway system and placed near the generators of high parking demand.

The remainder of the conference proceedings dealt with legislation, and enforcement. One presentation in particular by E. F. Kearney, Executive Director of the National Committee on Uniform Traffic Laws and Ordinances, dealt with the necessity of considering bicycles in traffic laws and ordinances.

The Transportation Engineering Journal of the ASCE has contained many articles within recent years dealing with bikeways. Desimone (August, 1973) deals with current practices, economics, and comprehensive design of bicycle facilities (9). Podolske deals with costs, location, and future needs of urban bike facilities (19). Transportation Research Record no. 508 (17) also deals with urban bike facilities in the form of four questions:

1. How much money should be spent on bike facilities?
2. What types of trips are the best candidates for bicycling?
3. What types of facilities should be provided?
4. Where should the facilities be located?

Many colleges and universities have dealt with their unique problem of highly concentrated bicycle usage by issuing statements regarding the institution's policy on bicycles. Examples reviewed for this study are from the University of California at Davis (11), the University of Illinois (3), Michigan State University (16), and Iowa State University (13). Topics generally covered by each of these institutions include: accidents, traffic control, and costs. All reports include the problem of parking, and state the necessity for placing racks as nearly as possible to the destinations. Trials were made with centralized bike parking at the University of California at Santa Barbara (4). The facilities fell into a state of disuse and were eventually converted into volleyball courts. The Bikeways Committee

Report (2) by the Ames - Iowa State Bikeway Committee states an objective of developing centralized bicycle parking to reduce pedestrian-bicycle conflicts. This is contrary to recommendations made in other reports, as previously mentioned, to locate parking facilities as nearly as possible to the destinations. The desirability of reducing bicycle-pedestrian conflicts is exemplified in the Bicycle Parking Update (10), January, 1976, by J. Harrod and P. Mahachek. This report is based on the primary objective that Iowa State University is a walking campus. The update also calls for centralized bicycle parking lots. A report entitled the Feasibility of Implementing a Walking Campus at Iowa State University, by L. H. Csanyi (8) on August, 1971, concludes that before a plan for a walking campus can be implemented, provisions must be made for an acceptable and efficient accommodation of displaced traffic.

Another topic commonly reported on is bicycle legislation. Articles regarding bicycle legislation can be found on an isolated basis in many newspapers. Four newspapers briefly reviewed for this study were the Los Angeles Times, the Washington Post, the Chicago Tribune, and the Christian Science Monitor. The November 21, 1972 issue of the Washington Post (23) relates the incident of 2400 cyclists demanding a hearing to voice problems of theft, parking and other hazards. The September 20, 1972 and September 26, 1974 issues of the Chicago Tribune (5, 6) give statistics of bike thefts in the Chicago area, and discuss methods of theft prevention. The March 11, 1974 issue of the Los Angeles Times (15) discusses the need for safer bike parking facilities at public places. The August 26, 1974 issue of the Christian Science Monitor (7) relays police suggestions for theft prevention, and also discusses bicycle insurance.

Of course, the commercial aspect of cycling is flourishing due to the recent bicycle boom. This is evidenced by an article in the August, 1971 issue of Playboy (18) magazine entitled "The Bicycle Boom." The commercial aspect is one which should receive consideration in the design of bicycle facilities, from the point of view that the increasing demand for bicycles has caused the cost of a bicycle to rise. One can easily spend several hundred dollars to purchase a quality bike. The fear of damage to an expensive bike may cause cyclists to not want to park in racks.

Though cycling as a transportation mode and as a means of recreation is often addressed, rarely is the topic of bicycle parking discussed to any great length. When the topic is discussed, it is done in general terms, suggesting basic guidelines to be used in the design of facilities, but no technical report regarding the determination of bicycle parking demand has been found. The topic of bicycle parking is generally covered in reports by universities, as those previously mentioned, since the problem is most severe on the campuses. The general concensus is that parking facilities should be located as conveniently as possible to building entrances.

CHAPTER III. PURPOSE, SCOPE AND PROJECT FACTORS

General Project Statement

The purpose of this thesis is to provide a feasible method of determining demand for bicycle parking on the Iowa State University campus. The method development will consist of 6 phases:

1. The campus will be divided into suitable zones for collection of bicycle parking data and for the relation of this data to appropriate destinations on campus.

2. A suitable factor, or group of factors will be determined with which to correlate observed bicycle parking data and make predictions regarding bicycle parking demand.

3. Bicycle parking data will be observed and collected for analysis.

4. A personal survey will be developed to determine general public preferences and activities with regard to bicycle parking on campus.

5. The data will be analyzed to determine the reliability of the factors chosen to model bike parking activity and to predict demand.

6. Conclusions and recommendations will be made, based on the analysis.

This methodology combined with other factors such as costs, design restrictions, and administrative policies which are outside the scope of this thesis may be used to develop a plan for improving bicycle parking facilities on campus.

Project Methodology

Initially, the locations of overcrowded facilities currently in use and the locations of concentrations of violations will be determined. This will be done by means of observation and counting of bicycles parked throughout campus.

The demand at individual locations will then be determined. After the demand analysis is completed, the optimal locations for new facilities and additions or deletions for existing facilities will be approximated in accordance with the previously determined demand.

In determining the location for new facilities, certain factors need to be taken into consideration. First of all, user needs and demands must be considered.

Associated with user needs is proximity to destination. The general location for bicycle parking facilities will be evaluated by determining the maximum distance cyclists are willing to walk from the facility to their destination. Once this distance is determined, an approximate area for acceptable location will have been defined. This is important, as has been stated before, since otherwise, the facilities will simply not be used by the cyclist.

Facilities located within acceptable walking distance must be placed in such a way that they are convenient to use. That is, there must not be any obstacles blocking direct access to facilities from a bicycle route or from a destination point. Unless this condition is met, the facility may fall into a state of disuse. This phenomenon has been observed and reported by the University of California at Davis. It has been attributed to overscreening of the bicycle parking facility by landscaping for aesthetic reasons.

A factor of importance that may have a tendency to be overlooked, is the need for security. Generally, bike parking facilities are tucked away, unobtrusively into corners for aesthetic purposes. This camouflaging, however, should not be done to the extent that hidden facilities become invitations for vandals and thieves. When possible, parking facilities should also be placed in areas that are lighted at night.

Safety considerations are also important in the design of bike parking facilities. The facility should be located so as to minimize pedestrian/bicycle/automobile conflicts. An article in the May, 1976 issue of the Transportation Engineering Journal of ASCE on bicycle accidents determined that the majority of accidents occurred at intersections. Since the intersection has the most conflict points, reducing these would lead to a reduction in accidents. As far as is practicable, the facilities should not be located in areas that would require the cyclist to ride his bike across streets and sidewalks to get to and from the bike path.

Along with safety factors, possible inconvenience to noncyclists must be considered. Parking facilities should not block or interfere with pedestrians or autos, as this may cause congestion, delays, and other inconveniences.

Project Scope

This study is limited to the Iowa State University campus. In determining the necessary number of facilities by considering user needs and demands, no attempt is made to determine the economic feasibility of providing the demanded facilities. This would depend on the cost of the necessary racks, pads, access routes, other accessories, and the funds available for them.

In determining the approximate location for the facilities by considering proximity to destination, easy use of facilities, security, safety, and possible inconvenience to noncyclists, only a minor emphasis will be placed on aesthetic considerations, as this is more appropriately done by a landscape architect.

Another factor is the possibility of additional lighting for security at night. Since this would entail considerable capital investment it will only be mentioned as a possibility in appropriate cases and is generally outside the scope of this thesis as far as the design of lighting facilities is concerned. Where lighting may be advantageous, it will be stated as such for appropriate locations.

CHAPTER IV: INVENTORY OF DATA

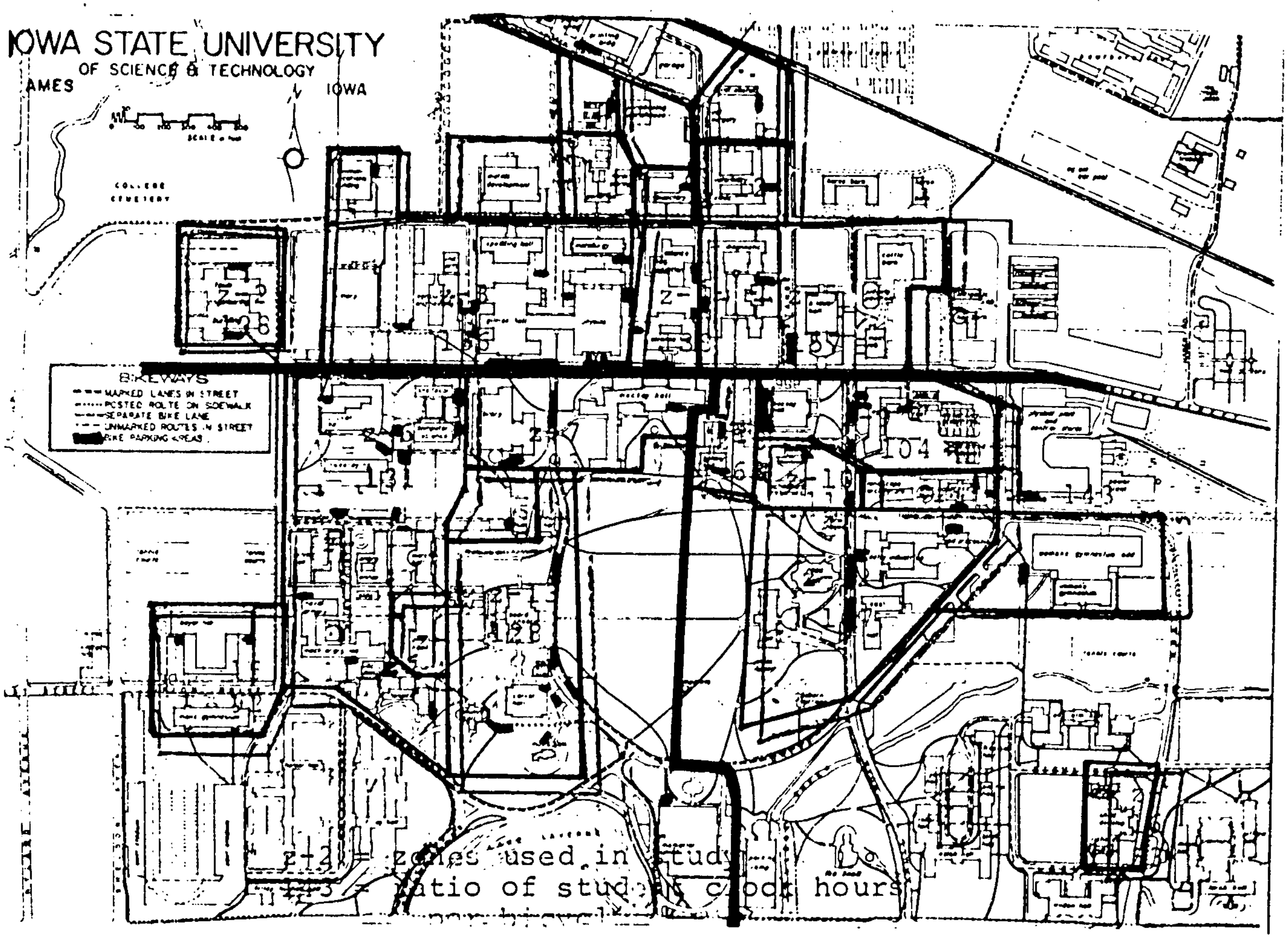
Two types of data collection are used in this study. One data collection procedure entails the counting of parked bicycles at locations on the Iowa State University campus. The bike counts provide the necessary data for bike parking demand determination.

The other data collection procedure entails the design and distribution of a personal questionnaire, hereafter referred to as the survey, of cyclists to determine their personal preferences regarding bike parking facilities. The survey results will display the demographical breakdowns of the respondents and their corresponding responses.

Bicycle Counts

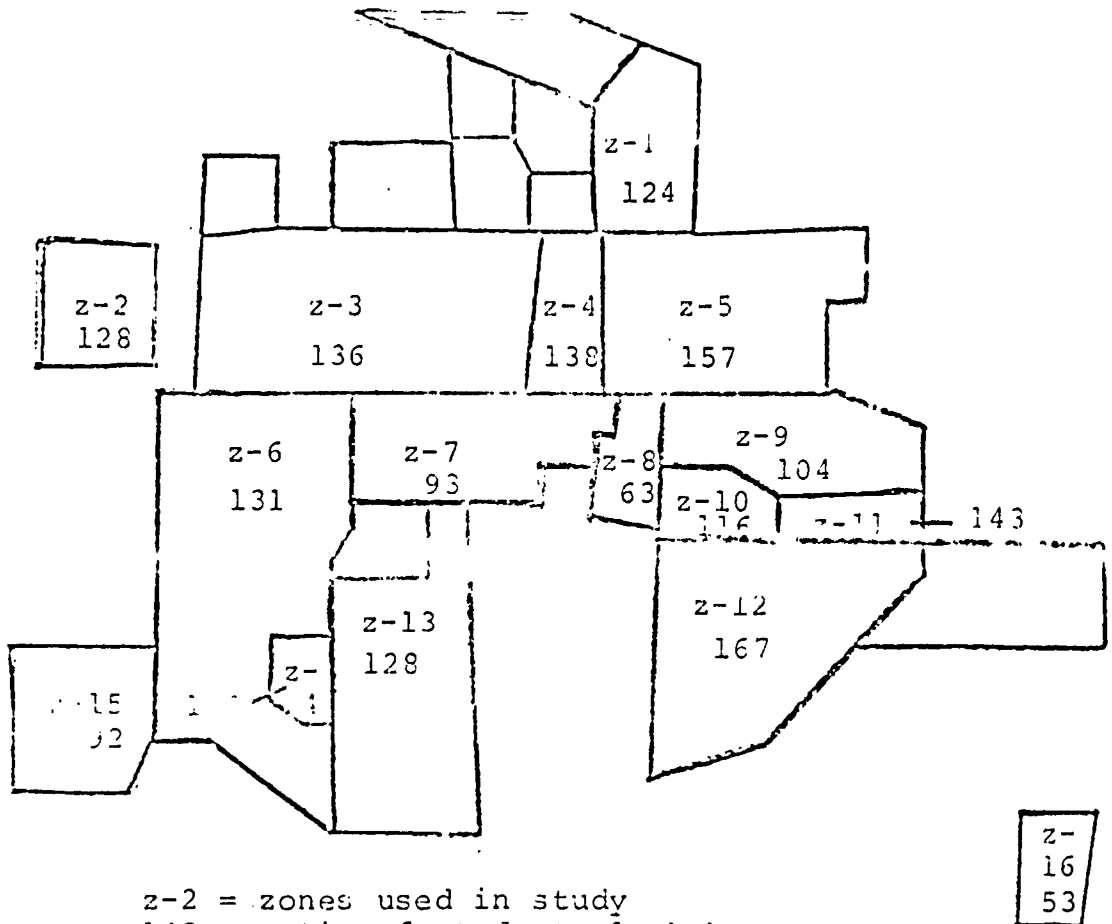
Initially, the campus was divided into 3 sections. This division is shown on the campus map on page 18, Figure 3, of the text. An individual counter was assigned to each zone. Bicycles in each zone were then counted over a two hour period. It had been previously determined by a trial count, that one third of the campus could be adequately covered in 2 hours. The counts were performed on 4 separate dates: Oct. 12, 1976, Oct. 20, 1976, Oct. 21, 1976, and Oct. 27, 1976.

Bicycle parking data were collected by a "spot count" procedure. This procedure was used as opposed to a continuous counting procedure for reasons of practicality. A continuous



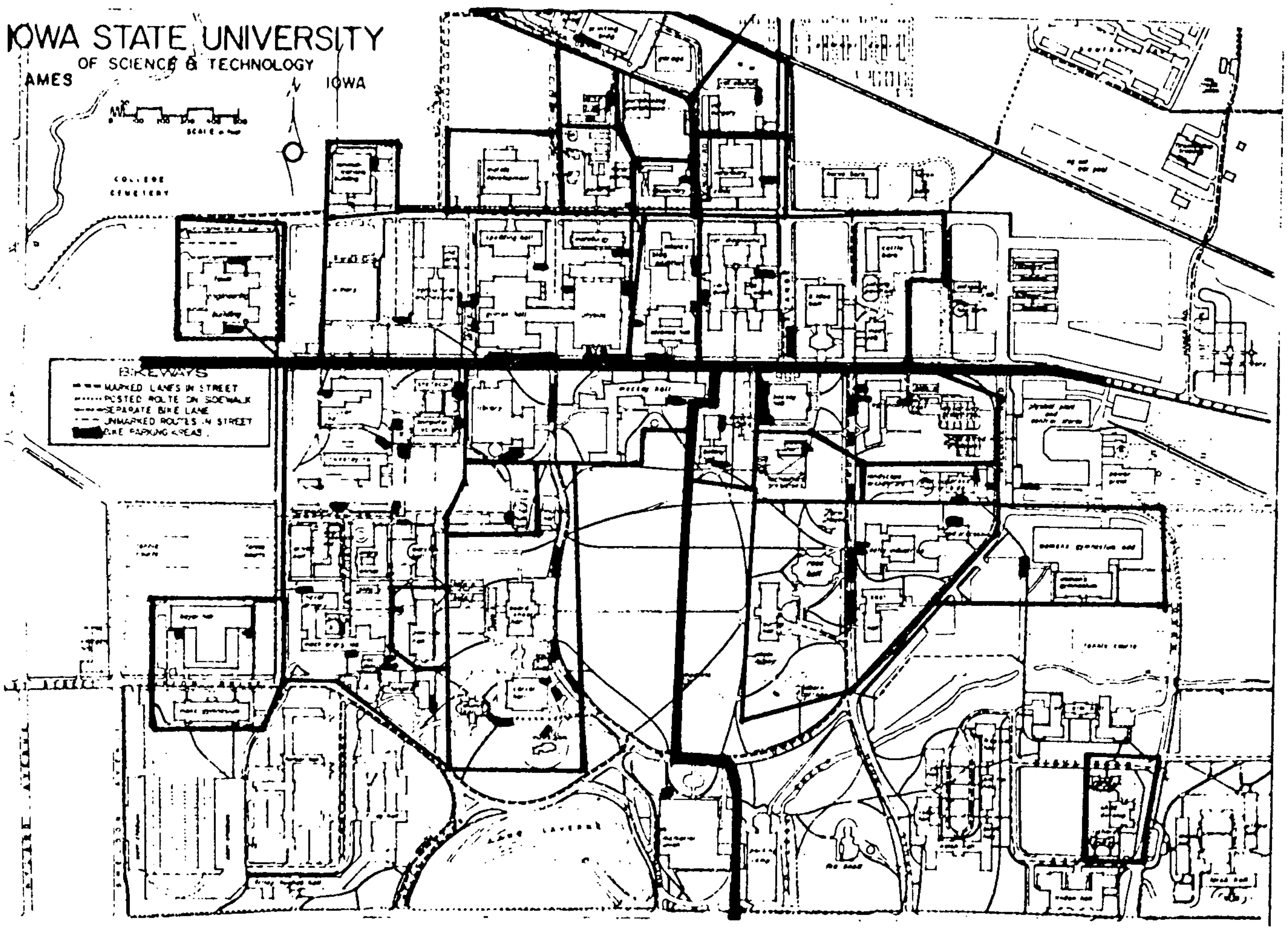
counting division line

Figure 2. Clock hours per peak bicycle for each zone
Figure 3. Zonal boundaries



z-2 = zones used in study
143 = ratio of student clock hours per bicycl

Figure 2. Clock hours per peak bicycle for each zone



counting division line

Figure 3. Zonal boundaries

count of all parking facilities simultaneously would have required excessive personnel, which were neither available nor affordable.

Two counts were made on each of the dates; the first count from 9 to 11 A.M., the second count from 1 to 3 P.M. These time periods were chosen because, from personal observation, they appeared to be the times of peak bicycle activity. The total number of bicycles counted, consisted of legally parked bicycles in racks, legally parked bicycles adjacent to racks, and bicycles in violation. The "spot count" procedure allowed all bicycles parked legally and concentrations of violations to be counted eight individual times.

Determination of Zonal Boundaries

Each bicycle counted was associated with a building, or a group of buildings which formed distinct zones. In most cases, due to the physical positioning of bicycle racks, it was difficult to determine which racks were used by cyclists destined for a particular building. Also, it was obvious from observation, that a single rack may be used by cyclists destined for several different buildings. It was for this reason that the campus was divided into zones. The definition of a zone, as used in this study, is, a distinctly bounded area of campus, within which, all parked bicycles may be associated with destinations also within the bounded area.

This definition is strictly a theoretical one as it is very possible that cyclists may park their bikes at one point and walk, interzonally, throughout campus. However, as was indicated by the survey, the vast majority of cyclists ride their bikes from destination to destination.

The zonal boundaries were determined by observation of the most probable parking place for a given destination as approached from all possible directions. In other words, to determine the zonal boundaries, an individual must ask, "Where would cyclists park their bicycles if destined for a specified building from a certain direction." Another factor involved, is determining for which buildings, cyclists would share an individual rack. One example of this is the racks on Knoll Road, which may be shared by cyclists destined for East Hall, Curtiss Hall, Ross Hall, and Dairy Industries.

The zonal boundaries, as determined for this study, are shown on the campus map on page 18, Figure 3.

Indicators of Bicycle Parking Activity

By far, the predominant users of bicycle facilities on campus are the students. This is obvious to anyone that witnesses the massive bike movements between class periods on a warm day. Since the vast majority of cyclists are students, an indicator of the expected number of bicycles parked in proximity of a classroom building may be a function of the number of students using that building. A convenient measure of student usage of a building is the student clock hour.

There are, however, other reasons that a student may use a classroom building. A library or sizable reading room, for example, in a classroom building may also draw students, thereby generating bicycle traffic and creating a demand for bike parking.

Data regarding the number of student clock hours associated with many buildings on campus were obtained from the Office of Space Utilization. The most recent data available were from the spring quarter of 1976. Upon questioning the applicability of the data to the fall quarter of 1976, personnel in the Office of Space Utilization made the statement that relative classroom building usage does not vary with great significance from quarter to quarter disregarding, of course, the summer sessions.

The data were available in the form of student clock hours per week for each individual building. The transparency accompanying the campus map, Figure 2, page 17, displays the ratio of student clock hours per peak number of bicycles counted in each zone. The number shown represents the number of student clock hours per single parked bicycle.

A readily obtainable form of data representing libraries and reading rooms on campus is the number of volumes in the library. These data were obtained from personnel at the major reading rooms and the main library on campus. The main library reported 1.1 million volumes. The architecture reading room in the Engineering Annex reported 2,500 volumes. The economics and sociology reading room in East Hall reported 4,580 volumes. The physical sciences reading room in the Office and Laboratory building reported 22,700 volumes. The engineering reading room in Marston Hall reported an estimate of 2,000 volumes. The factor of library volumes may prove to be a partial indicator of bicycle parking demand, especially near the main library.

Data Collection Procedure

Undergraduate and graduate students were hired to assist in the data collection effort. Each assistant was instructed as to proper data collection procedures for this study. The assistants were provided with standardized data collection forms which consisted of spaces to record location, approximate time, rack capacity, number of bicycles parked in the rack, number of bicycles parked legally adjacent to the rack, number of violations, total number of bicycles, and any comments.

The use of three assistants for two hour periods was necessary due to availability and affordability of personnel. Although the extensive counting period provided the potential for latitude and discrepancies in the observations from counting period to counting period, it was found to have a negligible effect. This may imply that during the chosen time periods for making bicycle counts, the demand for parking is relatively constant.

The Survey Questionnaire

It was decided that 200 completed survey questionnaires were desirable to give a representation of the attitudes of cyclists on campus. Since a return rate of approximately 30% was expected, 700 survey questionnaires were distributed. The surveys were distributed on November 4, 1976 between the hours of 10 and 11 A.M. They were placed on parked bicycles in proportion to the number of student clock hours associated with the building in closest proximity. In other words, the number of student clock hours was summed for the entire campus and randomly selected bicycles in the proximity of each building received a share of the 700 surveys equal to the fraction of the building's student clock hours divided by the total student clock hours.

The survey consisted of two pages. The first page contained instructions and questions about individual preferences. Questions were directed toward demographical breakdowns of male/female, student/faculty/staff, and major subject. The number of riding days per week was asked for. Respondents were asked to rate various factors pertaining to bike parking facilities according to the degree of importance. These factors are: nearness to destination, security, easy use of facilities, safety, lighted area (at night), paved area, and maintaining aesthetics on campus. The cyclists home origin was requested as well as the various destinations on campus travelled to during the day. Figure 4 is a copy of page 1 of the survey. The second page of the survey is a map of Iowa State University.

Iowa State University
BICYCLE FACILITIES SURVEY

A study is being conducted to determine the need for additional bike parking facilities on campus. Your cooperation is requested in completing the following survey.

- MALE or FEMALE
- STUDENT, FACULTY, or STAFF
- MAJOR SUBJECT ____________________
- INTERSECTION OF STREETS NEAREST YOUR HOME, or DORM NAME ________________

- How many days per work week (Monday-Friday) do you ride your bike to campus, assuming good weather? 1 2 3 4 5

- Rate the following factors on a scale of 1 to 5, corresponding to how important they are to you when determining where to park your bicycle:

	Not Important			Very Important	
Nearness to destination	1	2	3	4	5
Security	1	2	3	4	5
Easy use of facilities	1	2	3	4	5
Safety	1	2	3	4	5
Lighted area (at night)	1	2	3	4	5
Paved area	1	2	3	4	5
Maintaining aesthetics on campus	1	2	3	4	5
Others ________________	1	2	3	4	5

- PLEASE MARK YOUR RESPONSES TO THE FOLLOWING QUESTIONS ON THE MAP PROVIDED, USING THE APPROPRIATE SYMBOLS.

→ Use an "arrow" to show your usual point of entrance on the ISU campus.

X Use an "X" to show the usual first building you go to.

✓ Use a "check mark" to show any other buildings on campus, to which you ride your bicycle during the day.

● Use a "dot" to show where you usually park your bike at each of the building you marked.

Δ Use a "triangle" to show any buildings to which you walk and not ride your bike.

○ If adequate, safe, and secure bike parking facilities were provided, draw a ring around each building you marked, enclosing the greatest distance you would be willing to walk from these facilities to your destination.

PLEASE FOLD THE COMPLETED SURVEY FORM SO THAT THE ADDRESS SHOWS AND PLACE IT IN ANY BOX FOR CAMPUS MAIL AT ONE OF THE FOLLOWING LOCATIONS:

HUB EAST HALL PHYSICS BLDG. PHYSICAL PLANT DEPARTMENTAL OFFICES

THANK YOU

Figure 4. Page 1 of personal questionnaire

CHAPTER V. ANALYSIS OF SURVEY

Of the 700 surveys distributed, 226 were returned within one week. Surveys returned after this time were not tabulated. The return rate was 32.9 percent.

Breakdowns of survey respondents and parking facility preference factors are shown in Tables 1 and 3. Surprisingly, only 75.2 percent of the respondents were students, the remainder being faculty and staff. Perhaps this is an indicator that faculty and staff are more concerned with university associated problems or are more sympathetic towards graduate students attempting to write a thesis than are other students. Also 78.8 percent of the respondents were male which may indicate that the predominant number of cyclists on campus are male.

The responses to questions involving marking the provided map were varied, and many times were incomplete. Perhaps the questions were too time consuming or may have been difficult to understand. The statement which requested the respondent to circle an area surrounding each destination corresponding to an acceptable walking distance defied complete numerical analysis due to lack of care on the part of the respondents when circling the area and incompleteness. This method for determining acceptable walking distances was devised because it was believed that simply asking the

Table 1. Characteristics of survey respondents[a]

Category	Male	Female	No response
Students	136(60.2%)	34(15.0%)	--
Faculty	18 (8.4%)	5 (2.2%)	1(0.4%)
Staff	23(10.2%)	4 (1.8%)	--
No response	--	--	4(1.8%)

[a]23 = number of respondents; (60.2%) = percent of total respondents.

Table 2. Number of days per week riding bike to campus

Male			Female			No response		
m[a]	x[b]	r[c]	m[a]	x[b]	r[c]	m[a]	x[b]	r[c]
5	4.92	1-7	5	4.95	1-7	5	5	5

[a]m = most common response.

[b]x = mean response.

[c]r = range of responses.

respondents to state the numerical acceptable distance would give erroneous results. It is believed that the average respondent would not have been able to give an accurate response. The surveys which had this section completed generally indicated that the acceptable walking distance from

Table 3. Preferences of parking facility attributes

Facility attributes	Male			Female			No response		
	x[a]	m[b]	r[c]	x[a]	m[b]	r[c]	x[a]	m[b]	r[c]
Nearness to destination	4.82	5	1-5	4.63	5	1-5	4.00	3,5	3-5
Security	4.02	4	1-5	4.11	4	2-5	4.00	5	1-5
Easy use of facilities	4.72	5	1-5	4.24	5	1-5	3.25	3	3-5
Safety	3.86	4	1-5	3.94	4	1-5	4.50	5	3-5
Lighted area	3.24	3	1-5	2.12	2	1-5	2.50	1	1-5
Paved area	2.76	2	1-5	2.86	3	1-5	2.25	2	1-4
Maintaining aesthetics on campus	3.92	4	1-5	3.64	3	1-5	4.00	3,5	3-5

[a]x = mean response.

[b]m = most common response.

[c]r = range of responses.

parking facility to destination ranged from 50 to 450 feet. These values, especially the higher one, are questionable as can be observed from the numbers of violations right at building entrances. Therefore, when making recommendations, judgement and observation of violation concentrations will be used to approximate an acceptable walking distance. There were no distinguishing differences in acceptable walking distance with respect to any demographical breakdowns.

Though many of the surveys were incomplete, they generally indicated that student cyclists ride their bicycles to each of their destinations as opposed to parking at one location and walking to other destinations. The vast majority of cyclists ride their bicycles every day of the week, as exemplified by Table 2 on page 26.

Recommendations to be made in a subsequent chapter will be based partially on the results of the parking facility preference questions on the survey. As shown in Table 3 on page 27, nearness to destination and easy use of facilities were the factors of greatest preference. Maintaining aesthetics on campus and security were also rated highly. There were little differences in the responses of males and females except under the category of a lighted area at night. Surprisingly, the male respondents gave it an importance of 3.24 on a scale of 1 to 5, whereas the female respondents gave it an importance of only 2.12. Safety was also rated highly. The only factor not rated highly was the need for a paved area under the bike rack.

CHAPTER VI. ANALYSIS OF DATA

A computer program using SAS (Statistical Analysis System) was written to analyze the bicycle counts in linear regression models. The bicycle counts were broken down to represent several, potentially significant, dependent variables for each zone. They are: the peak number of bikes (peak bikes) of all counts in each zone, the total number of bikes for all eight counts in each zone, the total number of bikes counted on a specific day in each zone, the total number of bikes counted during the morning counts for each zone, and the total number of bikes counted during the afternoon counts for each zone.

A statistical t-test for paired observations was performed to determine if there was any significant change in the number of parked bicycles in each zone from day to day and also if there was any change between the total morning and afternoon counts. In all comparisons, there was no significant change at the 95 percent confidence level. This displays a relatively small variation in counts from day to day and between total morning and afternoon counts. The correlations among all of the aforementioned variables were calculated. In addition, three new variables were developed and included in the correlation matrix. They were: the peak number of bicycles that were counted in racks in each zone, the rack capacity in each zone, and the utility ratio. The utility ratio was defined as the peak number of bicycles in racks in each zone divided by the corresponding rack capacity of each zone. Each of the variables corresponding to bicycle counts had a coefficient of correlation with each of the remaining bicycle count variables of 0.99 or better. With respect to student clock hours in a zone, the highest correlation coefficient, 0.973, was obtained in relation to the peak bikes. This would logically appear to be the most appropriate design factor for three additional reasons:

1. The greatest number of cycles should be designed for, to reduce overflow to a minimum, thereby increasing safety.
2. Use of the other total bicycle count variables would imply that a knowledge of the overall peak time is needed to design for adequate facilities. On a university campus, such as Iowa State, this peak time may vary from building to building. The peak bikes count avoids this problem by using the greatest number of bikes at any time in each zone as the design factor.
3. The peak bikes count as a design factor would allow for growth in the number of bicycles demanding parking spaces without a concurrent great overflow which may be hazardous.

Each of the variables was individually tested in the linear regression model. Several possible independent variables were considered for analysis. These included student clock hours in each zone, library volumes in each zone, faculty and staff members in each zone, and special use rooms such as laboratories where students may do work outside of class. Faculty and staff members, and special use rooms were not deemed to be appropriate for analysis for several reasons. This study is aimed at the predominant cyclists on campus, the students. Faculty and staff would be concentrated where there are large volumes of students and would therefore be measuring approximately the same thing as student clock hours. Also, faculty and staff are not typically strong users of bicycle facilities. The generation of bicycle facility usage by special use rooms was deemed to be inappropriate for measuring facility demand for two reasons:

1. Such usage would be sporadic and, therefore, difficult to measure accurately.
2. The usage of such rooms would be light at any particular time, since it is nonscheduled. This would cause such a variable to have a negligible effect.

Peak bikes was used in each model as the dependent variable. First, student clock hours in each zone was used as the independent variable in the model. The use of student clock hours was able to explain 94.8 percent of the variation in the model. In the second model, the independent variables of student clock hours and library volumes in each zone were able to explain 96.7 percent of the variation. The incorporation of the other previously mentioned independent variables individually into the models caused the degree to which the variation could be explained by the models to fall within the range of 92.1 percent of 97.0 percent.

The equation which was selected as most appropriate for use in this study is as follows:

PKBIKS = 7.2 + 0.0070 (CLKHRS) + 0.069 (LIBR)

where PKBIKS = peak bikes

CLKHRS = student clock hours

LIBR = library volumes (in thousands)

These coefficients are significant at the .01 level.

Another indication of the validity of this model is that the constant term (7.2) is relatively small with respect to the mean number of peak bikes in each zone (147.4). This indicates that the changes in the dependent variable are quite sensitive to changes in the independent variables.

There were 16 zones for which student clock hour data were available. Tables 4 and 5, on pages 33 and 34, display each zone, its utility ratio, the zonal rack capacity, the corresponding student clock hours, and the peak number of

Table 4. Zonal student and bike activity

Zone	Total peak cycles	Total student clock hours	Clock hours/ bicycle
1	1	124	124
2	54	6,921	128
3	314	45,881	136
4	122	16,878	138
5	154	24,310	157
6	261	34,207	131
7	267	24,779	93
8	39	2,447	63
9	151	15,813	104
10	9	1,045	116
11	64	6,142	143
12	287	47,952	167
13	389	49,851	128
14	110	16,818	153
15	27	2,496	92
16	32	1,689	53

Table 5. Zonal parking characteristics

Zone	Utilization (%)	Rack capacity	Student clock hours	Violations
1	7.14	14	124	0
2	88.09	42	6,921	18
3	56.91	543	45,881	19
4	45.03	151	16,878	51
5	30.63	480	24,310	13
6	100.00	165	34,207	98
7	89.33	200	24,779	43
8	58.82	51	2,447	17
9	62.32	207	15,813	12
10	50.00	14	1,045	2
11	48.61	72	6,142	22
12	63.44	331	47,952	67
13	77.09	371	49,851	83
14	100.00	42	16,818	55
15	85.71	14	2,496	18
16	75.00	28	1,532	12

violations. A high degree of utilization with a high number of violations displays a need for additional parking facilities. A high degree of utilization with a relatively low number of violations indicates an adequate parking facility arrangement. On the other hand, a low degree of utilization with a high number of violations is indicative of improperly located facilities. A low degree of utilization with a low number of violations may display an over-designed parking facility.

The total number of bicycles in each zone must also be considered, as more bicycles will invariably mean more violations if all other factors are equal. However, the total number of violations must not be too high, no matter how many cycles there are.

On this basis, several zones display a need for redesign of parking facilities. Zone 3 has only a 57 percent utilization with 19 violations. Though 19 violations compared with 45,881 student clock hours is small, the violations are concentrated at door entrances and are hazardous to pedestrians. Zone 4 has only a 45 percent utilization with 51 violations. These violations are also concentrated near door entrances.

Zone 5 displays only a 31 percent utilization with 13 violations. The low degree of utilization is due to the large parking lot on Stange road, west of Kildee Hall, that is not used to the degree which must have been anticipated in its design. Zones 8, 9, 11, 12, 13, and 16 also display low degrees of utilization with a fair number of violations. This indicates that a relocation of parking facilities may be justified, and some additions may be needed.

Zones 1 and 10 have low rates of utilization as well as low numbers of violations. Both zones have very little bicycle activity and currently have an appropriately minimal bicycle parking capacity.

Zones 2, 6, 7, 14, and 15 have high degrees of utilization of their bike parking facilities as well as high numbers of violations. This was especially true in zone 6, which had 100 percent utilization and 98 violations. This means that each rack group in this zone was full at some time during the parked bicycle counts, and not that all the rack groups were full at the same time. These zones are definitely in need of increased parking capacity.

CHAPTER VII. RECOMMENDATIONS

General Criteria

Generally, bicycle parking facilities at Iowa State University are reasonably well designed from the point of view of having sufficient capacity. This is evidenced, at least partially, by the 0.86 correlation coefficient between student clock hours and rack capacity for each zone.

Tables 4, 5, 6 and 7 show the rack capacity, utilization, peak bikes, student clock hours, violations, and predicted demand for each zone and classroom building. The predicted demand was calculated from the regression equation determined by the computer analysis of the independent variables. The independent variables are student clock hours and library volumes (in thousands). The regression equation, as determined by the computer analysis for estimating peak bikes, is:

$$PKBIKS = 7.2 + 0.0020\ (CLKHRS) + 0.069\ (LIBR)$$

where PKBIKS = peak bikes

CLKHRS = student clock hours

LIBR = library volumes (in thousands).

Table 6 also shows the change needed in each zone. This was determined in a general fashion with three options: increase racks, relocate (decrease) racks, or no change. Increasing the racks was deemed appropriate when the predicted

Table 6. Predicted parking demands by zone

Zone	Existing rack capacity	Predicted demand	Change needed
1	14	8	--
2	42	55	increase racks
3	543	328	relocate racks
4	151	125	relocate racks
5	480	176	relocate racks
6	165	245	increase racks
7	200	267	increase racks
8	51	24	relocate racks
9	207	117	relocate racks
10	14	14	--
11	72	50	relocate racks
12	331	341	increase and relocate racks
13	371	354	relocate racks
14	42	124	increase racks
15	14	25	increase racks
16	28	26	relocate racks

Table 7. Predicted parking demands by building

Building	Student clock hours	Predicted demand
Ag. Engineering	13,057	98
Agronomy	5,982	49
Andrews-Richards	157	8
Armory	786	13
Beardshear	1,751	19
Bessey	9,831	76
Beyer	2,496	25
Bio. Med. Eng.	42	7
Botany	2,198	22
Carver	47,135	335
Ceramics Studio	249	9
Child Development	1,532	18
Computer Science	2,680	26
Coover	9,064	70
Curtiss	11,968	90
Dairy Industry	9,064	70
East Hall	8,073	64
Engineering Annex	3,682	33
Engineering Research Inst.	1,170	15
Exhibit Hall	1,847	20
Gilman	20,652	151
Horticulture	187	8
Hort. Greenhouse	1,045	14
Industrial Ed.	1,328	16
Judging Pavilion	1,314	16
Kildee	13,880	104
Landscape Arch.	3,023	28
LeBaron	11,795	89
Library	2,067	97
MacKay	10,917	83
Marston	11,757	89
Mechanical Eng.	474	10
Lab of Mech.	2,694	26
Morrill	965	14
Music	3	7
Naval Armory	1,138	15
Nuclear Eng. Lab	38	7
Pearson	16,818	124
Physics	11,386	88
Pope Cottage	78	8
Press	6,142	50
Ross	18,847	138
Science	8,202	64
Science II	8,676	68

Table 7 (Continued)

Building	Student clock hours	Predicted demand
Snedecor	2,833	27
Sloss	415	10
Stange Clinic	1,475	17
Student Health Serv.	93	8
Sweeney	2,397	24
Town Engineering	6,921	55
Vet Diagnostic Lab	4,239	37
Vet. Med. Quad.	4,877	41
Women's Gym	7,831	62
Vet Obstetrics	124	8

demand exceeded the existing rack capacity. Relocating the racks is the appropriate change when the utilization is low. The necessity of each change is amplified if the data indicate a high number of violations in conjunction with insufficient rack provisions or low utilization.

Recommendations concerning security and safety are most appropriately made on an individual location basis. This procedure seems best due to the variation in geometrics, degree of usage, pedestrian volumes and potential conflicts from location to location.

Zone 1

Zone 1 has relatively little bicycle activity. Existing facilities, therefore, are adequate in numbers and suitably located. The only lighting is on the exterior of the buildings, but it is adequate. Though utilization is only 7 percent, the low volume activity does not justify any facility alteration.

Zone 2

The utilization in this zone, which comprises Town Engineering Building, approaches 90 percent. There were 18 violations and a peak count of 54 bikes (12 bikes over capacity). This indicates that the existing facilities are well located and that an increase in rack capacity is needed. The predicted demand of 55 bikes calls for an increase of 13 spaces. The additional rack space would be most appropriately located on the south side of the building since the observed data indicate all violations to be concentrated here. Lighting is adequate at all parking locations. There is noticeable difficulty with bicycle/pedestrian conflicts on the sidewalk approaching the south entrance of Town Engineering Building. A possible alternative to alleviate the conflicts would be to locate the bike parking area on the east side of the building, which is seldom used by pedestrians. This may be objectionable from an aesthetic point of view.

Zone 3

The utilization in zone 3 is only 57 percent. The main reason for this, is that the rack capacity is 543 spaces, whereas, the predicted demand is only 328 bikes. The peak number of bikes counted is 314, including 19 violations. These data display the need to relocate some racks in this zone and possibly remove some as well. All violations in this zone were observed at the south entrances of Gilman Hall and the Physics building. The greatest concentration of misallocated parking spaces in this zone is southeast of the Armory. The rack capacity here is 56 spaces, whereas the peak count was only 11 bikes. The racks southeast of Spedding Hall have a capacity of 49 spaces and a peak count of only 21 bikes. The racks south of Gilman Hall and the Physics building are overflowing. It is recommended that the misallocated racks be moved to the south entrances of Gilman Hall and the Physics building.

Lighting in this zone is generally adequate. Facilities are relatively easy to use. Pedestrian/bicycle conflicts are minimal, as the cyclists generally ride on Osborn Drive.

Zone 4

Zone 4 has a utilization of 45 percent, a rack capacity of 151 spaces, peak count of 122 bikes, and a predicted demand of 125 bikes. There were 51 violations observed in this zone. The data indicate a need for relocation of facilities. The violations are concentrated near the south entrance of Science Hall and at the south entrance of Science II. The greatest concentration of misallocated racks is composed of those bordering Osborn Drive. There are 98 spaces available here, of which only 31 were used, as observed in the peak count. The fact that Science Hall is somewhat set back from the curb parking facilities on Osborn Drive may account for the high number of violations on the south side of the building. It is recommended that the misallocated racks be moved to the south side of Science II. Placing racks near the south entrance of Science Hall may cause pedestrian/bicycle conflicts on the sidewalk leading to the entrance, but this may be better than the existing clutter of bikes at the south door. Lighting in this zone is found to be adequate.

Zone 5

A very low utilization of 31 percent has been observed in zone 5. This is the result of an existing rack capacity of 480 spaces, a peak count of only 154 bikes, and a predicted demand of only 176 bikes. Violations are sufficiently dispersed to be negligible. The high misallocation of spaces is concentrated in the racks west of Kildee Hall on Stange Road. This location may have been designed as an attempt at centralized bike parking. The excess racks would be more appropriately located in other areas of campus to preclude the purchase of additional racks. Lighting is sufficient and pedestrian/bicycle conflicts are minimal.

Zone 6

Zone 6 is in need of increased parking facilities. This is evidenced by a peak count of 261 bikes, a predicted demand of 245 bikes, an existing rack capacity of only 165 spaces, and a utilization of 100 percent. Concentrations of violations were observed at the east and west entrances of the Computer Science building, the east side of Coover Hall, between the Mechanical Engineering Lab and the Lab of Mechanics, the east side of Snedecor Hall, and the west side of Marston Hall. Based on the predicted demand for buildings as shown in Table 7, on page 39, it is recommended that approximately 25 spaces be added between Coover Hall and the Computer Science building. An additional 35 spaces should be provided near the west entrance of Marston Hall, and 14 spaces should be provided near the east entrance. In this area the racks east of the Engineering Annex are used extensively by individuals going to Marston Hall, as was somewhat indicated by the survey. This series of racks should be increased by approximately 30 spaces as evidenced by the large number of overflow bikes. An additional 10 spaces would be appropriate between the Mechanical Engineering Lab and the Lab of Mechanics. An additional 10 spaces is also recommended for the east side of Snedecor Hall. Lighting is adequate throughout the zone and pedestrian/bicycle conflicts due to improper parking locations do not appear to be a problem.

Zone 7

An increase in the number of racks is recommended for zone 7. The predicted demand and peak count were both 267 bikes. The rack capacity is 150 spaces and utilization is 89 percent. The concentrations of violations were observed at the south entrance of the library and the west side of LeBaron Hall. An additional 20 spaces is recommended for the south side of the library. Since all the bikes associated with LeBaron Hall and MacKay Hall appear to be concentrated on the west side of LeBaron, it is recommended that an additional 45 spaces be located here as nearly as practicable to the entrance. A large number of pedestrian/bike conflicts take place on the sidewalk on the south side of the library. This appears to be unavoidable due to the high volumes of both pedestrian and bicycle traffic necessarily sharing the sidewalk.

Zone 8

A 59 percent utilization, 17 violations, a rack capacity of 51 spaces, a predicted demand of 24 bikes, and a peak count of 39 bikes display a need for relocation of parking facilities in zone 8. However the illegally parked bikes were dispersed indeterminably. No positive recommendation can be made regarding the facility location. The lighting east of the Ceramic Studio is poor. If there is any significant degree of use after dark, it is recommended that the lighting be improved.

Zone 9

The predicted number of bikes for zone 9 is 117 and the existing capacity is 207 spaces. The low utilization of 62 percent and 12 concentrated violations display a need to relocate a portion of the facilities. The violations were concentrated at the east entrance of Bessey Hall. The concentration of unused racks is on Knoll Road to the east and southeast of Bessey Hall. It is recommended that approximately 15 spaces be provided near the east entrance of Bessey Hall. Lighting in this zone is generally quite good and pedestrian/bicycle conflicts appear minimal.

Zone 10

Zone 10 has no problems regarding bicycle parking. The existing capacity and predicted demand both equal 14 bikes. Lighting is good and pedestrian/bicycle conflicts are negligible.

Zone 11

Zone 11 displays a need for facility relocation. The existing rack capacity is 72 bikes whereas the predicted value is 50 bikes. The utilization is 49 percent. The concentration of 22 violations exists entirely at the south entrance of the Landscape Architecture building. It is recommended that the misallocated racks be removed from Knoll Road west of the Landscape Architecture building and 28 spaces be provided at the south entrance. Lighting in this zone is good. There is a great number of pedestrian/bicycle conflicts on the sidewalk south of the Landscape Architecture building. These could be avoided by the construction of a bike way connecting Wallace Road and Knoll Road adjacent and parallel to this sidewalk.

Zone 12

Zone 12 displays a need for increased facilities as well as relocated facilities. The 67 observed violations in this zone are evenly distributed and concentrated on the north and west sides of Ross Hall and on the west side of Curtiss Hall. The racks on Knoll Road just west of the Dairy Industries building are not used to capacity, as evidenced by the 63 percent utilization. It is recommended that 50 spaces be moved from Knoll Road to the north side of Ross Hall. Dairy Industries must maintain the 70 spaces within closest proximity to the west entrance. It is also recommended that 25 spaces be provided on the west side of Curtiss Hall, 15 of which, are to be taken from Knoll Road. The other 10 spaces are additional. Provision of bike parking facilities on the north and west sides of Ross Hall and Curtiss Hall may cause excess pedestrian/bicycle conflicts. However, the existing clutter of bicycles, especially around Ross Hall, can be equally as dangerous. Lighting in this area is good.

Zone 13

The number of parking facility spaces allocated to zone 13 is adequate. The main problem is locational. There were 83 violations observed, 73 of which were associated with Carver Hall. It is recommended that 335 spaces be provided as nearly as practicable to the entire perimeter of Carver Hall. Considering the facilities on Morrill Road, approximately 35 spaces should be retained between Morrill Hall and Beardshear Hall. The remainder of these spaces are not optimally used and should be moved to Carver Hall. Portions of the hard surfaced area between Carver Hall and Beardshear Hall would make an excellent bike lot, but may cause conflicts with pedestrians. The area is well lighted.

Zone 14

Zone 14 is comprised of Pearson Hall. The utilization is 100 percent and 55 violations were observed. The existing rack capacity is only 42 spaces, whereas, the predicted demand is 124 bikes. The violations were concentrated on the east side of the building. Therefore, it is recommended that approximately 80 spaces be provided on the east side of Pearson Hall. This could possibly take the form of a small lot between Pearson Hall and Building H. The violations are mostly chained to fences and trees along the sidewalks north-east of Pearson Hall. The construction of a small lot, would cause pedestrian/bicycle conflicts, but the bicycles are currently being ridden on the sidewalks anyway. The lot would organize the existing clutter of parked bikes. Lighting is adequate in this area.

Zone 15

Zone 15 includes Beyer Hall and State Gym. There were 18 observed violations, 11 of which were near State Gym. The predicted demand is 25 spaces, however, since the buildings function as gymnasiums the usage may be much higher during time periods other than class time. It is recommended that approximately 15 spaces be provided near the State Gym entrances and an additional 20 spaces be provided near Beyer Hall entrances, based on observed violations. Lighting in this zone is adequate.

Zone 16

Zone 16 displays a need for relocated racks due to a 75 percent utilization and 12 violations. It is recommended that the racks be moved closer to the main entrances of Richards-Andrews and Nickel-Fisher. Lighting is adequate and pedestrian/bicycle conflicts are negligible.

Comments on Surveys

Many of the returned surveys had comments written on them regarding the campus bicycle facility system in general. One comment made repeatedly, was a suggestion for an additional bike path across central campus in an east-west direction. Another repeated comment was a plea to not ban bicycles from campus. This comment is a result of a recent article in the Iowa State Daily and assorted rumors concerning the possibility of banning bikes from campus. No recommendations are made regarding these comments. They are mentioned to display the more common attitudes of the campus bicyclists.

Nonclass Associated Bicycle Activity

Table 8 on page 51, displays the bicycle parking activity associated with the Union, Hub, and dormitories on campus. The Union and Hub offer no substantial problems regarding bike parking. Violations around the Union were dispersed.

The dormitories offer a special problem, in that their peak usage is probably overnight. The counts in Table 8 were taken during the regular counting interval during the day, therefore, no recommendation can be made regarding them. It is in an area such as the dormitories, where the lots are mainly used for long term parking, that a more centralized system may be feasible.

Table 8. Nonclassroom bicycle activity

Building	Rack capacity	Peak bicycles	Violations
Union	135	51	8
Hub	21	13	0
Barton Hall	68	41	0
Birch Hall	10	4	0
Buchanan Hall	112	82	9
Elm Hall	98	107	11
Freeman Hall	56	48	1
Friley Hall	60	61	22
Helser Hall	70	70	23
Knapp Hall	200	237	40
Larch Hall	124	140	25
Linden Hall	77	73	2
Lyon Hall	39	47	6
Maple Hall	213	186	32
Oak Hall	59	63	4
Roberts Hall	79	54	0
Storms Hall	200	206	22
Wallace Hall	280	175	0
Welch Hall		N/A	
Westgate Hall		N/A	
Willow Hall	138	175	8
Wilson Hall	280	271	47
Vet Complex		N/A	

CHAPTER VIII. CONCLUSIONS

It has been observed that in general, the northern and eastern sections of campus have been oversupplied with bike racks whereas the western section is under-supplied. Ratios of the existing facilities to the predicted demand for these areas show the following: The northern part of campus, comprising of zones 1, 2, 3, 4, and 5 has an existing to predicted ratio of 1.78. The western section of campus, comprising of zones 6, 7, 13, 14, and 15, has an existing to predicted ratio of only 0.78. The eastern section of campus, comprising of zones 8, 9, 10, 11, 12 and 16 has an existing to predicted ratio of 1.23. Overall, if racks are properly allocated, the total number of spaces on campus may be reduced by approximately 16%.

Generally, the demand determination procedure used in this study has proven to be excellent, at least on the zonal level. The necessary parking spaces to be provided for each building individually should not be totally based on this procedure for several reasons.

1. Excessive costs may be involved to properly install the facilities near entrances.
2. It may be quite feasible to provide small lots which satisfy the demand, and are within acceptable walking distance of more than one building.
3. Spaces are not available individually. Racks which typically consist of 7, 10, or 14 spaces must be used. Therefore, the exact, predicted demand cannot be provided.

CHAPTER IX. FUTURE STUDY POSSIBILITIES

Adequate facilities for bicycle parking is a critical problem on many college and university campuses. This study has investigated and demonstrated only one approach to this problem.

There are other aspects to bicycle parking not covered in this study which may be of some value if analyzed.

One contributor to violations is the fear of bike damage due to unstable racks. This is especially true for cyclists with expensive bicycles. Investigating what type of rack design would be both economical and provide a low damage threat may provide a solution to this problem.

Another factor of possible value would be the effects of different penalties on violations with respect to bike parking. Investigations as to what would be an economical but thorough method of enforcement is needed for the campus bike system. A suggestion for this topic would be an analysis on a benefit-cost basis. Benefits may possibly be measured as the reduction in parking violations for each increment of fine increase times the incremental fine increase in dollars.

An addition to this project may be a procedure involving a continuous count. This would involve a great deal of time, and personnel, but may indicate if violations are at least partially due to over-crowded racks at short time intervals, such as between class periods. Also, it would more precisely define the peak traffic period that a spot count procedure can only approximate.

Better records of bicycle accidents may show points on campus where adjustments need to be made for safety reasons. Existing accident records at Iowa State University are insufficient, because most bicycle accidents are not reported.

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