ED 031 055

EF 003 416

By-Fouad, Monira Y.
Campus Transportation Planning. A Case Study of the Lafayette Campus of Purdue University. Final Report.
Indiana State Highway Commission, Indianapolis., Purdue Univ., Lafayette, Ind.
Report No-JHRP-9-12-2
Pub Date Feb 69
Note-148p.
EDRS Price MF-$0.75 HC-$7.50
Descriptors-*Campus Planning, Facility Case Studies, Facility Guidelines, *Facility Requirements, Facility
Utilization Research, *Parking Facilities, Pedestrian Traffic, *Traffic Circulation, *Transportation, Vehicular
Traffic

The problems and future requirements related to transportation on the Purdue University, Lafayette campus, are examined. After identifying a central academic zone, future requirements are estimated related to the pedestrian circulation system, pedestrian-vehicle conflicts, parking facilities, and mass transportation systems in the zone. A number of alternate plans are developed to meet the future needs of circulation within the academic zone as well as those of commuters. Recommendations are also made as to which plan ought to be implemented. A bibliography is included. (FS)

AMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

FEBRUARY 1969 – NUMBER 5
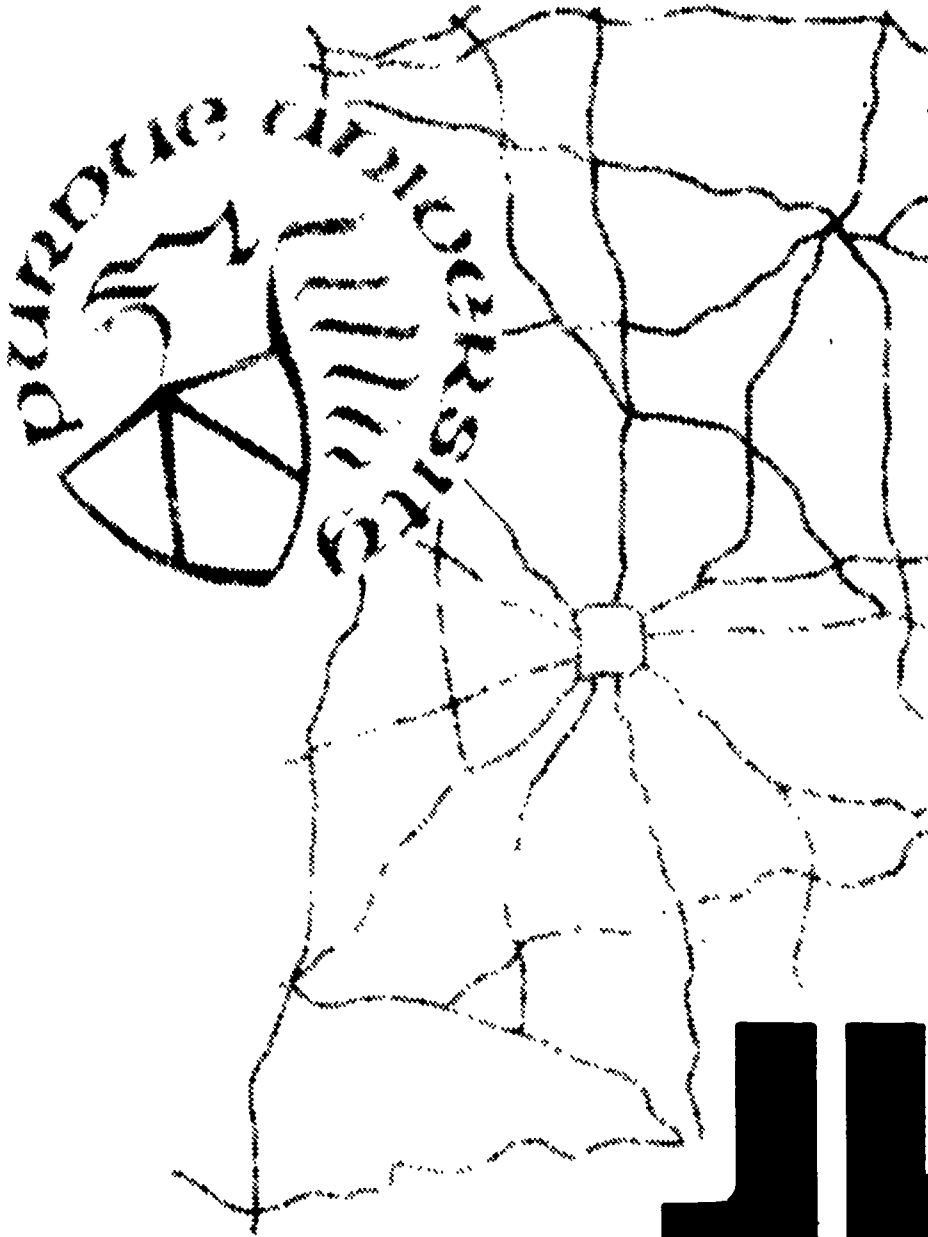
BY

MONIRA Y. FOUAD

JHRP

JOINT HIGHWAY RESEARCH PROJECT
PURDUE UNIVERSITY AND
INDIANA STATE HIGHWAY COMMISSION

Final Report

CAMPUS TRANSPORTATION PLANNING: A CASE STUDY
OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

To: J. F. McLaughlin, Director   February 16, 1969
    Joint Highway Research Project
                                         File 9-10-2

From: H. L. Michael, Associate Director
      Joint Highway Research Project

The attached Final Report "Campus Transportation Planning: A
Case Study of the Lafayette Campus of Purdue University" has been
prepared by Mrs. Monira Y. Foued under the direction of Professor
H. L. Michael. The research was financed by Purdue University.
Mrs. Foued also used the report as her thesis for the MS degree.

The study examined the future requirements of transportation on
the Purdue Lafayette Campus. A number of feasible plans are examined
to meet these transportation requirements for an ultimate campus
population of 35,000 students.

The report is presented to the Board as information.

Respectfully submitted,

Harold L. Michael
Associate Director

HLM:rg
Attachment

Copy:

F. L. Ashbaucher	R. H. Harrell	C. F. Scholer
W. L. Dolch	J. A. Havers	M. B. Scott
H. H. Coetz	W. L. Harvey	W. T. Spencer
W. L. Grecco	G. A. Leonards	H. R. J. Walsh
G. K. Hallock	F. B. Mendenhall	K. B. Woods
M. E. Harr	R. D. Miles	E. J. Yoder

Final Report

CAMPUS TRANSPORTATION PLANNING:
A CASE STUDY OF THE LAFAYETTE CAMPUS
OF PURDUE UNIVERSITY

by
Monira Y. Fouad
Graduate Assistant in Research

Joint Highway Research Project
File No: 9-12-2

Purdue University
Lafayette, Indiana
February 14, 1969

ACKNOWLEDGMENTS

Miss J. Bodenhafer, Main Library; Miss A. E. Limbach, Cafeteria Manager, Memorial Union; Mr. R. J. Caroll, Sweet Shop Manager; and Miss N. L. Clerget, Home Economics Food Service, for the generous time and efforts they gave to make available the data used in this study.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

ABSTRACT

Fouad, Monira Yehya. M.S., Purdue University, June
1969. CAMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE
LAFAYETTE CAMPUS OF PURDUE UNIVERSITY. Major Professor:
Harold L. Michael.

This study examined the problems and future require-
ments related to transportation on the Purdue Lafayette
campus. A number of feasible alternative solutions were pro-
posed to meet future transportation requirements for an es-
tablished ultimate campus population.

On the campus, a central academic zone was identified
as the locus of instructional, research, administrative, and
assembly facilities. Pedestrian and automobile circulation
in this zone and commuting to and from it were analyzed.
Future requirements related to the pedestrian circulation
system in the academic zone, to the major pedestrian-vehicle
conflicts in and around the academic zone, and to parking
facilities for students, staff, and visitors and/or mass
transportation systems serving them were estimated.

A number of alternative plans were developed to meet
the future needs for circulation in the academic zone and
for commuting to and from it. These alternatives were eval-
uated in terms of cost as well as a number of other quali-
tative criteria. It was found by eliminating through

vehicular traffic on the north campus and by connecting it
to the south campus through an open pedestrian underpass
under State Street, that future pedestrian-vehicle conflicts
in the academic zone could be minimized. Implementation of
such a plan would only require reasonable changes in the·
existing conditions.

Insofar as commuting to and from the academic zone is
concerned, two plans appeared to offer appropriate solutions.
One of these by providing for future parking demands of
students, staff, and visitors on close-by locations around
the academic zone (mostly in multi-story garages) would
offer a high level of convenience in terms of the trip times
involved. The second by providing for the future parking
demands in remote parking facilities connected to the aca-
demic zone by street bus systems would offer a lower annual
cost than that of the first plan but not as high a level of
convenience. It was recommended that the first plan be
implemented.

CHAPTER I.   INTRODUCTION

In many respects, a university campus resembles a city.
Frequently, the size of the campus population (students,
staff, and visitors) comes close to that of a small city.
The activities performed on the campus are almost as complex
and diversified as those performed in the city. The campus
is not only a place for learning, for research, and for the
development of the society's cultural life, but also a place
where people live, work, shop, and move. To such extents,
a university campus can be conceived as a micro-city to
which many urban planning and transportation concepts are
applicable.

In recent years, university campuses started to face the
problems of population expansion. Their facilities, once
simply laid out in close proximity to each other, had to
expand upwards as well as outwards. Movement to and from
these facilities and between them became more complex, in-
tense, and time consuming. "Like most municipalities in
the United States," writes Jakad, "American colleges and
universities have come face to face with the explosive traf-
fic problem." (1, p. 47)*

---

* Numbers in parentheses refer to numbered items in the
  List of References.

Both the campus population and the surrounding community suffered. Students are often obliged to walk longer distances than what is generally considered tolerable. They have to rush between classes to move from one building to another and in many cases, they have to cross heavy vehicular traffic. In the same time, automobile trips to the campus have become more difficult and time consuming due to lack of parking facilities on or around the campus. Traffic problems are equally felt by students, staff, and visitors. The surrounding communities also suffer from the intense traffic generated by the expanding campuses. The rapidly increasing enrollments and the mounting rates of automobile ownership and usage appear to be the two major factors behind campus transportation problems.

At already existing campuses, transportation problems are rendered even more severe by the inherited physical layout of buildings and circulation systems. At relatively old campuses, efforts were seldom made to provide an automobile-free environment. As a result, typical layouts inevitably create pedestrian-vehicle conflicts, especially in the central area of the campus where both pedestrian and vehicular traffic take place most intensely.

While many concepts and solutions have been presented to overcome (or at least to minimize) transportation problems for newly developed campuses, relatively little has been done to explore the possibilities of relieving existing

campuses of such problems. The need exists to develop appropriate techniques to examine and analyze the transportation problems at already existing campuses as well as to develop sound and practical solutions to meet them.

Purpose and Scope

Purpose

The purpose of this study.was to examine the nature and extent of the transportation problems on an already existing campus and to develop a number of alternative solutions to meet its future transportation requirements. The campus investigated in this study was the Lafayette campus of Purdue University. The study had the following specific objectives:

1. To develop an appropriate technique (or techniques) for examining the nature and magnitude of the transportation problems on an existing campus where the majority of the students were not commuters.

2. To estimate, for an ultimate campus population, the future campus transportation requirements.

3. To develop feasible alternative solutions to meet these estimated requirements.

4. To provide the decision-makers in the university with the necessary facts and evaluations about these developed alternatives.

Scope

In this study, the future campus transportation requirements are estimated for an ultimate campus population regardless of the future date at which this ultimate population might be reached. The study is limited to the investigation of campus transportation problems created by the traffic movements to and from as well as within the academic zone. As used in this study, traffic movements include both automobile and pedestrian traffic. The academic zone is defined as the locus of the contiguous instructional, research and administration functions of the campus. Traffic movements generated (or attacted) by peripheral areas of the campus represent a negligible fraction of the total traffic generated by the campus and are not considered in this study. Traffic routes to and from the surrounding community are also outside the scope of this study.

Emphasis is given to the movements of students to and from as well as within the academic zone. Movements of staff and visitors are also considered. Due account is given to the access of service and emergency vehicles.

Two main aspects related to campus transportation are analyzed: (1) pedestrian movements to and from as well as within the academic zone, and (2) parking demands of students, staff, and visitors on and around the academic zone.

The Lafayette Campus

The location of the Purdue Lafayette campus as related
to the urban area (Lafayette and West Lafayette) is shown
in Figure 1. The campus is located just west of the central
business area of the city of West Lafayette and southwest
of Northwestern Avenue, a major urban arterial. State Street,
another major arterial, passes through the campus and a
railroad line bounds it from the south. Community residen-
tial areas abut the east and northeast sides of the campus
and open recreational areas surround both its west and north-
west sides. Purdue's enrollment on this campus (23,370 in
1967/68) is, and has been, larger than what could be entirely
accommodated by privately owned community housing facilities.
The university, therefore, provides a substantial portion
of the students' housing requirements. A general layout of
the Purdue Lafayette campus appears in Figure 2.

Within the campus, the academic zone was delineated as
the area where instructional, research, administrative, and
principal assembly facilities are located. Figure 2 shows
the delineation of the academic zone. State Street divides
the academic zone into two parts referred to in this study
as the north and the south campuses.

Previous Studies

Campus transportation problems are often studied in con-
nection with campus physical planning. Few are the studies,
however, that were primarily concerned with aspects of campus

Lafayette and West Lafayette
Indiana
1968

KEY

U.S 52 BY-PASS
URBAN ARTERIALS
URBAN LAND WITHIN THE CORPORATE LIMITS OF LAF. AND W. LAF.
PURDUE UNIVERSITY LAFAYETTE CAMPUS
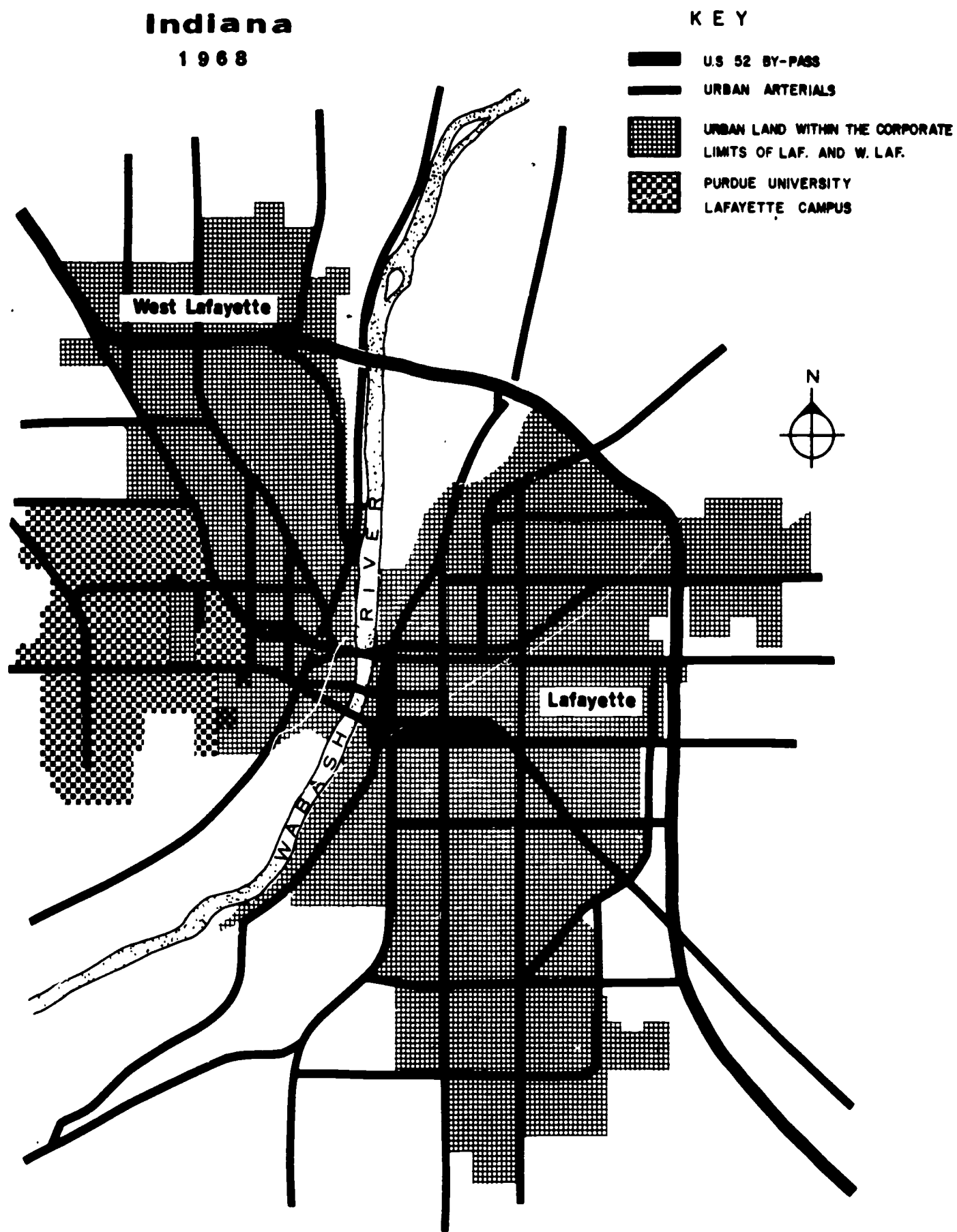
FIGURE I — PURDUE UNIVERSITY LAFAYETTE CAMPUS — GENERAL LOCATION

PURDUE UNIVERSITY LAFAYETTE CAMPUS

1968

0 _ . _ . _ .
FEET

N

☐ UNIVERSITY BUILDINGS

- - RAILROAD

ACADEMIC ZONE

UNIVERSITY HOUSING

ATHLETIC FACILITIES

OPEN SPACES

SHOPPING CENTER

PURDUE AIRPORT

SERVICES & STORAGE

NORTH CAMPUS

SOUTH CAMPUS
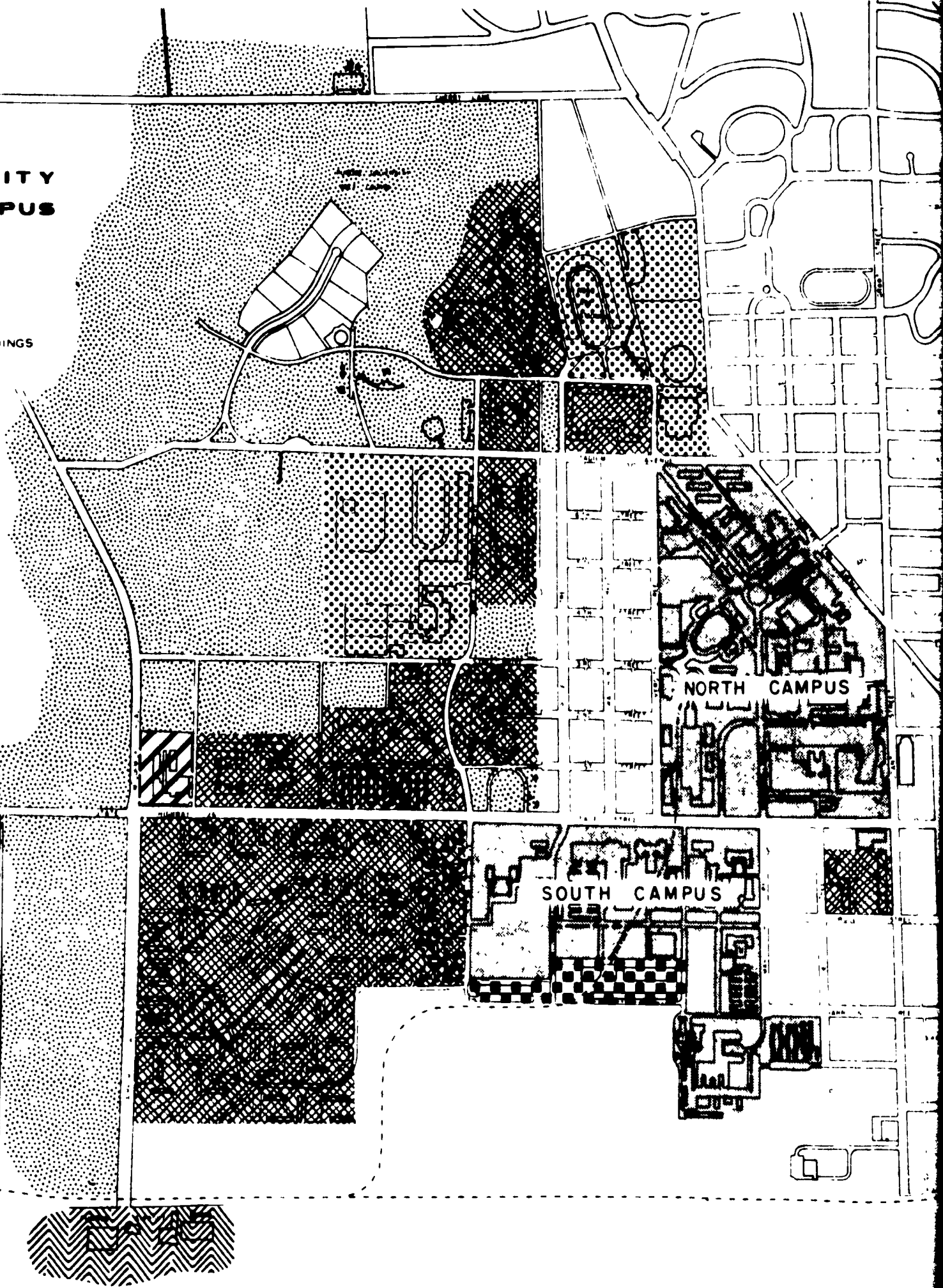
FIGURE 2 — PURDUE UNIVERSITY LAFAYETTE CAMPUS — GENERAL LAYOU

W A B A S H   R I V E R

NORTH CAMPUS

SOUTH CAMPUS
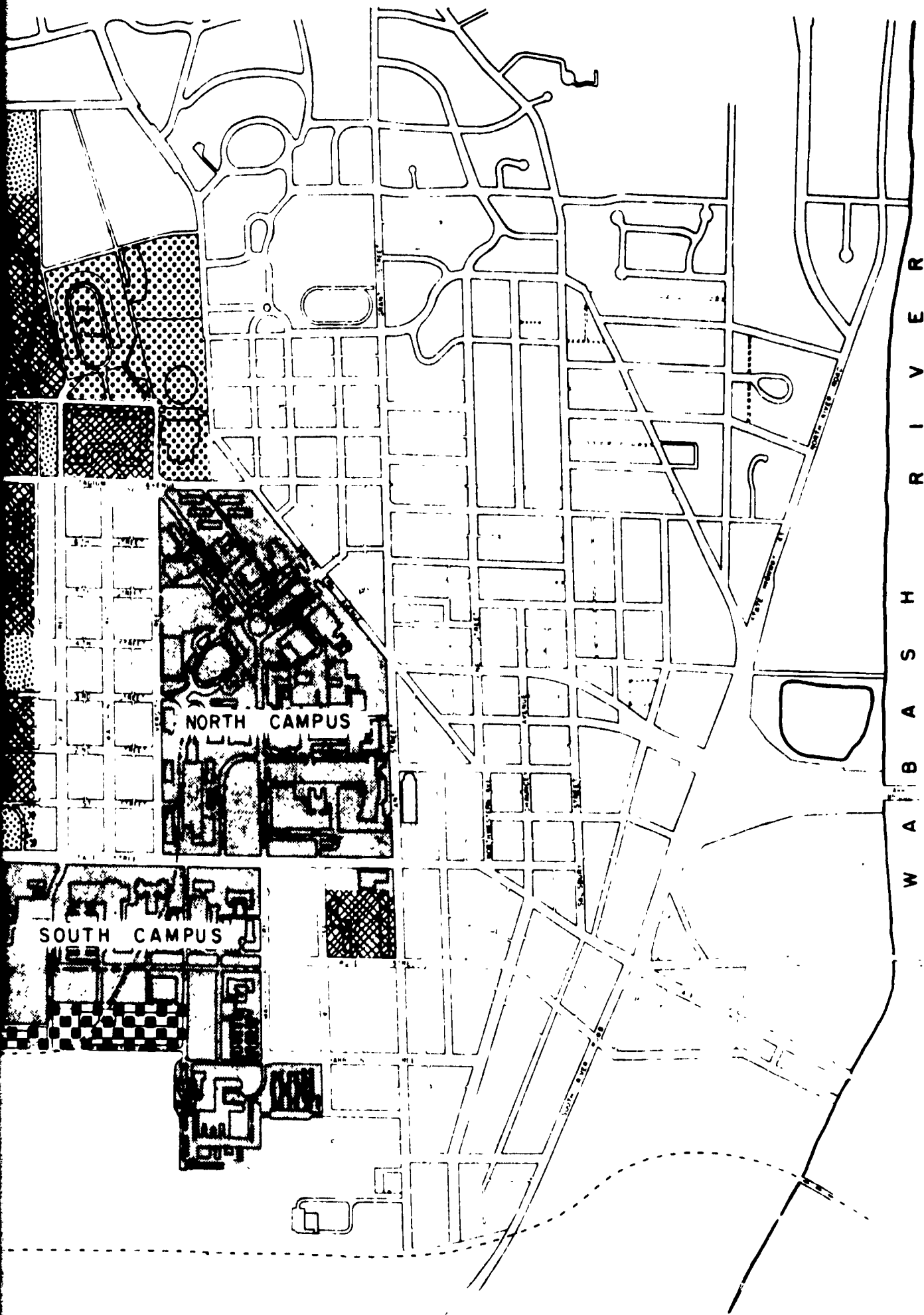
MPUS — GENERAL LAYOUT

transportation. Fewer still are those directed to comprehensive campus transportation planning.

To examine the pedestrian traffic generated by students on university campuses, the Educational Facilities Laboratories and Duke University developed a computer aided technique to simulate pedestrian traffic patterns by using information reported by a sample of students in the form of diaries. By means of the proposed technique, existing pedestrian traffic maps can be plotted. Future pedestrian traffic volumes and patterns can also be estimated (2). While the technique is conceptually sound, it has a number of operational limitations. The difficulties of obtaining diary information and the conceivable inaccuracies involved in using them (especially in forecasting) tend to limit the usefulness of the technique.

The University of Michigan and the University of Mississippi used an observed vehicle trip generation rate per capita (to the campus) to estimate future vehicular traffic (3,4). Although Dober recognized the simplicity of using such observed rates, he pointed out that consideration should be given to other factors such as changes in university housing supply, changes in the populations of graduate and married students, improvements in mass transportation systems, and increasing campus parking supply (5).

In preparing parking plans for the University of Illinois and the University of Mississippi, Bartholomew & Associates

stressed the importance of considering vehicle ownership trends in estimating parking demands. He also pointed out that the policies adopted by the university relative to parking supply, fees, and controls have a great influence on parking demand. Accordingly, Bartholomew developed a number of alternative parking plans assuming different levels of future demand. The level of demand that could be economically met was, then, selected. The university's future parking policies were planned accordingly (4,6). Provided that the assumed alternate levels of parking demand are realistically established on the basis of observed parking habits and patterns, this approach can provide sound estimates of future campus parking requirements.

Marconi investigated the factors affecting parking demand on two different campuses in San Francisco. He found that parking demand was substantially higher on the campus that had the higher percent of non-resident students (7). In essence, these results indicated that the distances from the students' residences to the campus have a decisive effect on the rates of automobile usage and consequently on the parking demand.

The variables most often pointed out in the several studies found in the literature as influencing campus traffic and parking demands are: (1) size and composition of the campus population, (2) proportion of resident students living in university housing facilities, (3) class schedules

and office hours, (4) availability and conditions of mass transportation, (5) university parking policies, and (6) parking availability and fees in the surrounding community (3-8).

While variables affecting campus transportation have been separately recognized and used, it appears that no comprehensive technique has yet been developed to include a combination of these variables in estimating future campus traffic and parking demands.

Procedure

In this study, two major phases of campus transportation are considered. First, movement in the academic zone is examined. The efficiency of pedestrian circulation is analyzed in terms of trip lengths and frequencies. Inefficiencies in the existing layout and uses of instructional facilities are pointed out. Locations and intensities of pedestrian-vehicle conflicts are also discussed. Second, commuting to and from the academic zone is subjected to a detailed analysis. Four campus population characteristics are considered to have a combined effect on the numbers of trips made to and from the academic zone in different hours and on the modes of travel used in these trips. First, the size and composition of the campus population (students, staff, and visitors) is used in determining the magnitude of traffic movements to and from the academic zone. Second, the numbers of users of instructional facilities, offices,

and other assembly facilities in the academic zone (referred to in this study as the daytime population) provides the basis for examining the temporal patterns of traffic movements to and from the academic zone. Third, the students' behavioral patterns in using their automobiles to and from the academic zone are examined. Based on these patterns, probabilities of automobile usage by students living at different distances from the academic zone are established. Fourth, the residential distribution of students (both in university housing facilities and in the surrounding community housing) is used to establish the proportions (and numbers) of students living at different distances from the academic zone. On the basis of the observed patterns of automobile usage, the students' residential distribution is used to estimate the expected numbers of student auto trips (and non-auto trips) made to the academic zone. Since almost all staff members and visitors, regardless of where they live, tend to use their automobiles to commute to the academic zone, their residential distributions were not considered.

The present university regulations on traffic and parking, the existing conditions of relative parking availability on and around the academic zone, and the existing patterns of automobile usage in commuting to the academic zone are assumed to remain almost unchanged for the future.

For an established ultimate campus population, the future patterns and magnitudes of vehicular and pedestrian traffic movements in as well as to and from the academic zone are

estimated on the basis of the above assumptions and the analyses of the existing traffic movements. Future transportation requirements (in terms of pedestrian walkways, parking facilities, and/or mass transportation systems) are determined. Several alternative plans are developed to meet the future needs for circulation in the academic zone and for commuting to and from it. These alternatives are evaluated in terms of cost as well as a number of other qualitative criteria. Conclusions are drawn and recommendations made.

CHAPTER II.   DATA COLLECTION, DATA ANALYSIS,
AND FORECASTING

The following is a discussion of the data collected
for this study, the analyses performed on each data item,
and the forecasting of future conditions relevant to campus
transportation planning. In the following discussions, the
term student is used to indicate full-time and part-time
registered students. By staff is meant all full-time mem-
bers of the faculty and of the clerical and service staffs.
Instructional facilities refer to buildings where classes or
laboratory sessions are held.

Movement in the Academic Zone

Movement in the academic zone is mainly done by foot.
Vehicular movement is relatively limited. However, pedes-
trian-vehicle conflicts exist at certain locations in the
zone. The analysis of the movement in the academic zone,
therefore, focused on two aspects: (1) the efficiency of
pedestrian circulation (and the general layout of the dif-
ferent facilities), and (2) the pedestrian-vehicle conflicts.
Since students represent the majority of pedestrians in the
academic zone, only their movement was considered. The
analysis provided the basis for developing proposals to min-
imize pedestrian-vehicle conflicts and for making

recommendations on the future layout of facilities in the academic zone. Student pedestrian trips are unique in that their origins and destinations (in the academic zone) are mainly dictated by class schedules, the time-break allowed between classes, the locations of the existing facilities, and the use of these facilities. The analysis, therefore, took into consideration these fundamental temporal and spatial determinants of pedestrian circulation in the academic zone.

The Efficiency of Pedestrian Circulation

Ideally, facilities most used in common should be centrally located to be most accessible from all other locations in the academic zone. Instructional facilities should also be located within "walkable" distances from each other; "walkable" within the time-break allowed between classes. Under these ideal conditions, a relationship between pedestrian trip lengths and trip frequencies would show a high frequency of short trips with a decreasing frequency as trip length increases. Such an ideal pattern may not be found on all existing campuses. However, an analysis of the existing relationship between trip lengths and frequencies provides a measure of the degree to which the ideal is fulfilled. The analysis was thus performed as follows.

For each instructional facility in the academic zone, the weekly total number of student contact hours was used to estimate the average daily pedestrian trips attracted by

the facility (9).* Non-instructional facilities were not
considered. Estimates on average daily pedestrian trip
ends by facility were obtained for both the Spring and Fall
semesters of 1967. Results obtained for both semesters did
not show appreciable differences. Figure 3 shows groupings
of instructional facilities according to their estimated
average daily pedestrian trip ends for the Fall of 1967.
Presently, the time-break allowed between classes is ten
minutes, about two minutes of which are usually spent in
going in and out of classrooms and going up and down stair-
cases at both origin and destination. The actual walking
should thus be done in eight minutes. Because instructional
facilities are presently classified and used by major
fields (Electrical Engineering, Physics, Chemistry...etc.)
and not by functions (lecture halls, laboratories, offices...
etc.), linkages exist (from a circulation standpoint) be-
tween each instructional facility and virtually all others.

To examine the efficiency of the existing layout of
facilities and the pedestrian circulation system, a hypothet-
ical non-problematic circular zone was delineated whose di-
ameter can be walked within eight minutes at an average
speed of about 275 feet per minute.** By superimposing the

---
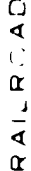
 * A student contact hour refers to one student attending one
   instructional session. Every class contact hour and every
   three laboratory contact hours were considered equivalent
   to one pedestrian trip.

** A recent standard observed in a survey conducted at
   Cornell University (10).

PURDUE UNIVERSITY LAFAYETTE CAMPUS

1968

☐	UNIVERSITY BUILDINGS
- -	RAILROAD
■	INSTRUCTIONAL FACILITIES
◯	BOUNDARY OF THE ACADEMIC CORE
◯	FOCAL POINT

AVERAGE DAILY PEDESTRIAN TRIP ENDS

2,000 OR MORE	
801 — 2,000	
201 — 800	
1 — 200	

N
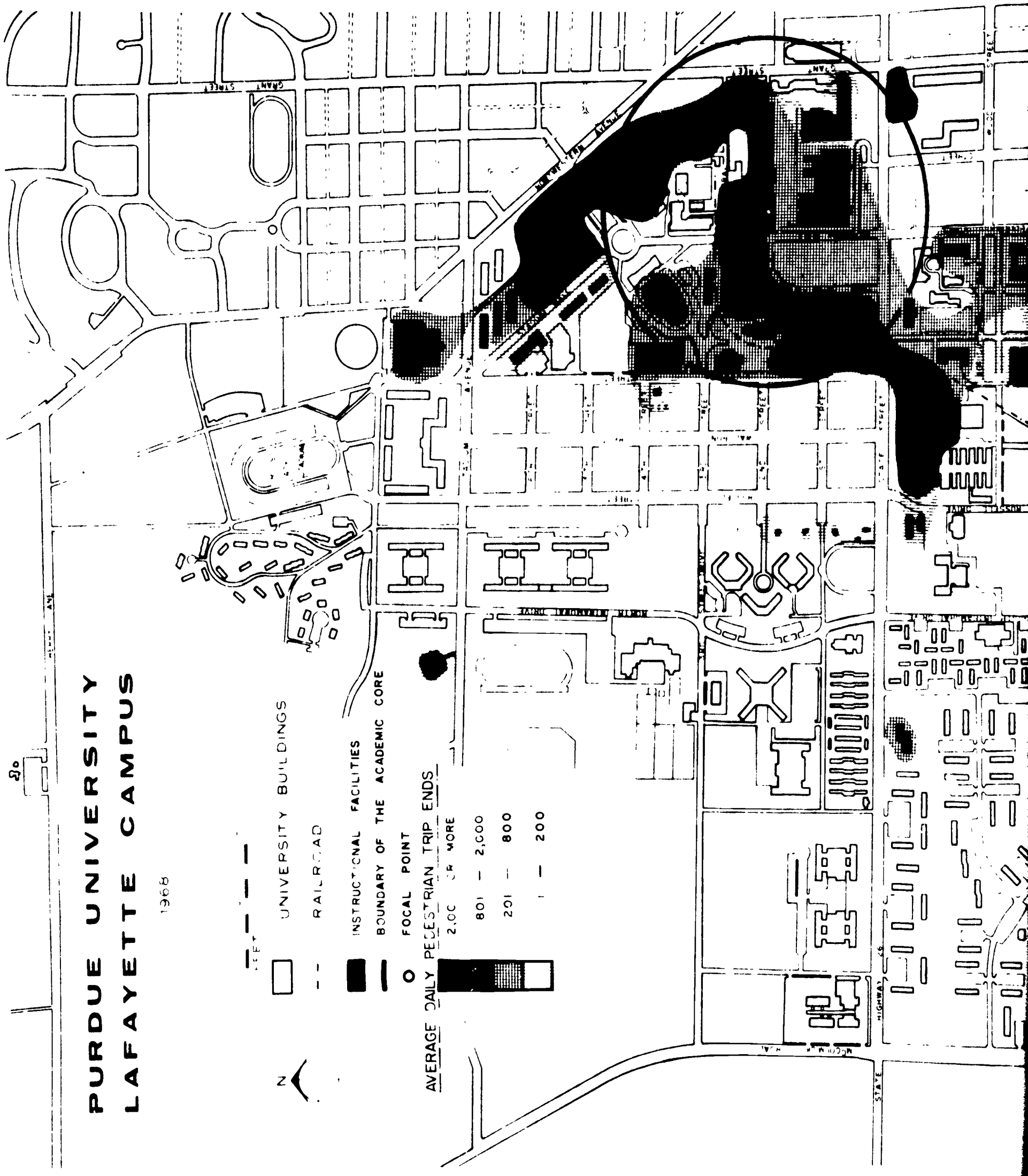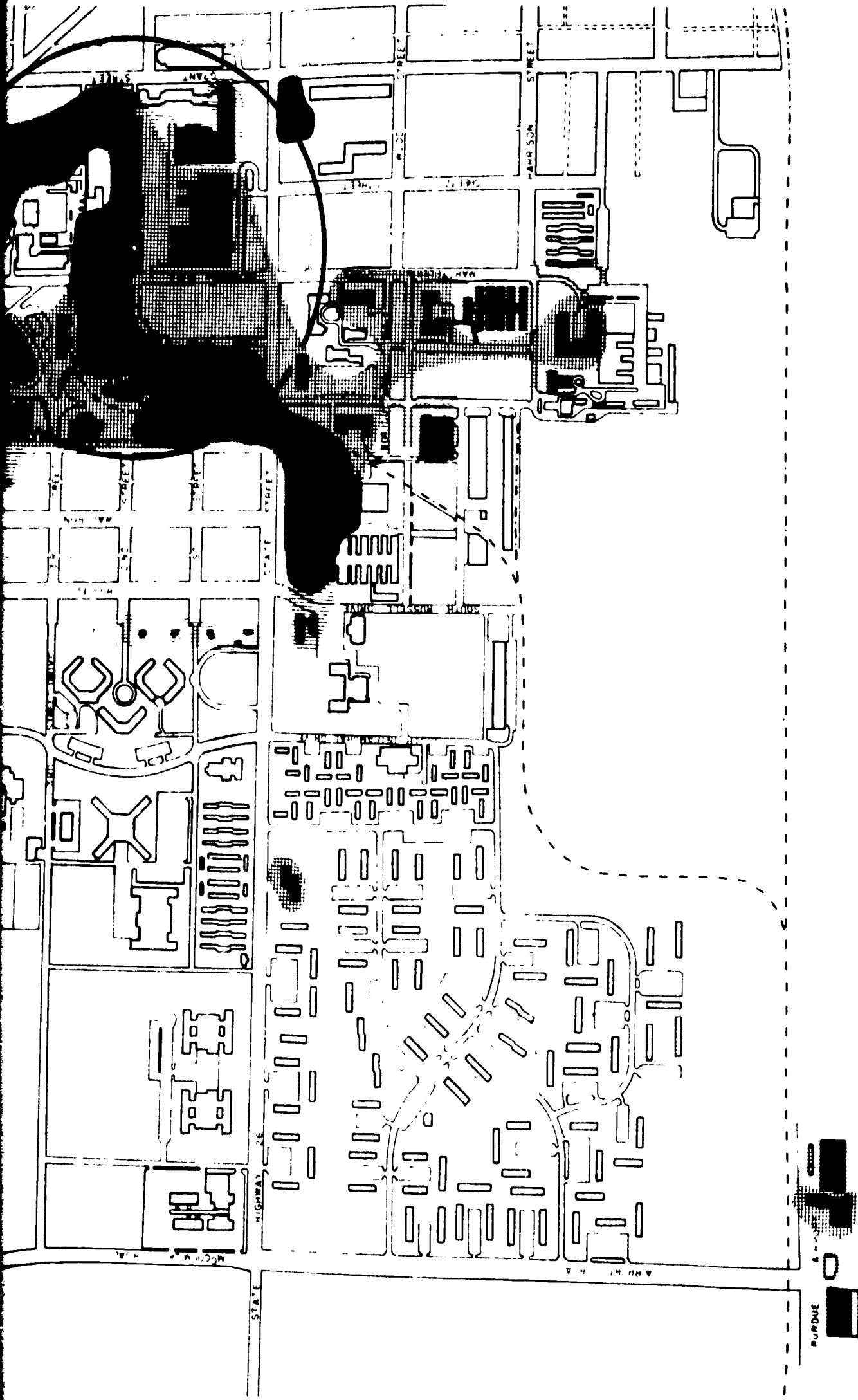
FIGURE 3 — AVERAGE DAILY PEDESTRIAN TRIP ENDS TO INSTRUCTIONAL
FACILITIES, FALL 1967

hypothetical zone on a map of the existing academic zone, a position was found that allows inclusion, within the non-problematic "core," of the maximum number of instructional facilities with the highest frequencies of use (Figure 3). The center of this "core" (referred to later as the focal point) was considered as the theoretical center of the academic zone. The actual trip lengths from the focal point to each instructional facility were measured and a relationship between trip lengths and frequencies was established. Figures 4 and 5 give the estimated average daily pedestrian trip ends by instructional facility by distance from the focal point for the Spring and Fall semesters of 1967.

The analysis shows that pedestrian trips exist that cannot be walked in eight minutes. However, no conclusive data were available to show how many such trips had to be made between two consecutive classes. Thus, the magnitude of these problematic trips could not be determined. The analysis, however, indicates that the present layout and use of the instructional facilities within the academic zone does not provide the most efficient linkages between facilities and hence does not minimize pedestrian travel. Some heavily used instructional facilities are located outside the non-problematic "core" (e.g., Life Science and Physics Buildings) while inside it are located some totally non-instructional facilities (e.g., the Engineering Administration building, the heating and power plant, and the Heavilon
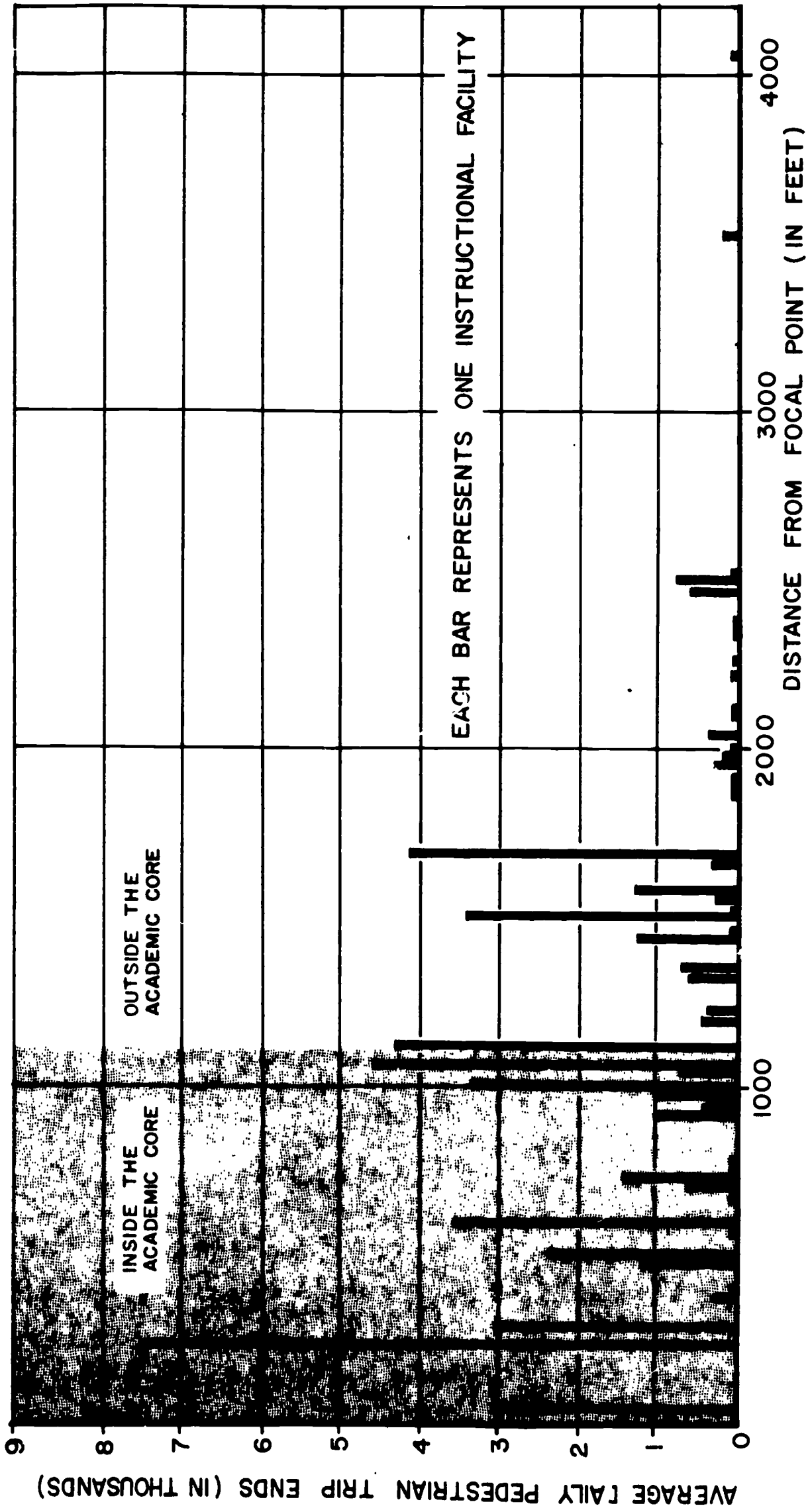
FIGURE 4 — AVERAGE DAILY PEDESTRIAN TRIP ENDS BY INSTRUCTIONAL
FACILITY BY DISTANCE FROM THE FOCAL POINT, SPRING 1967
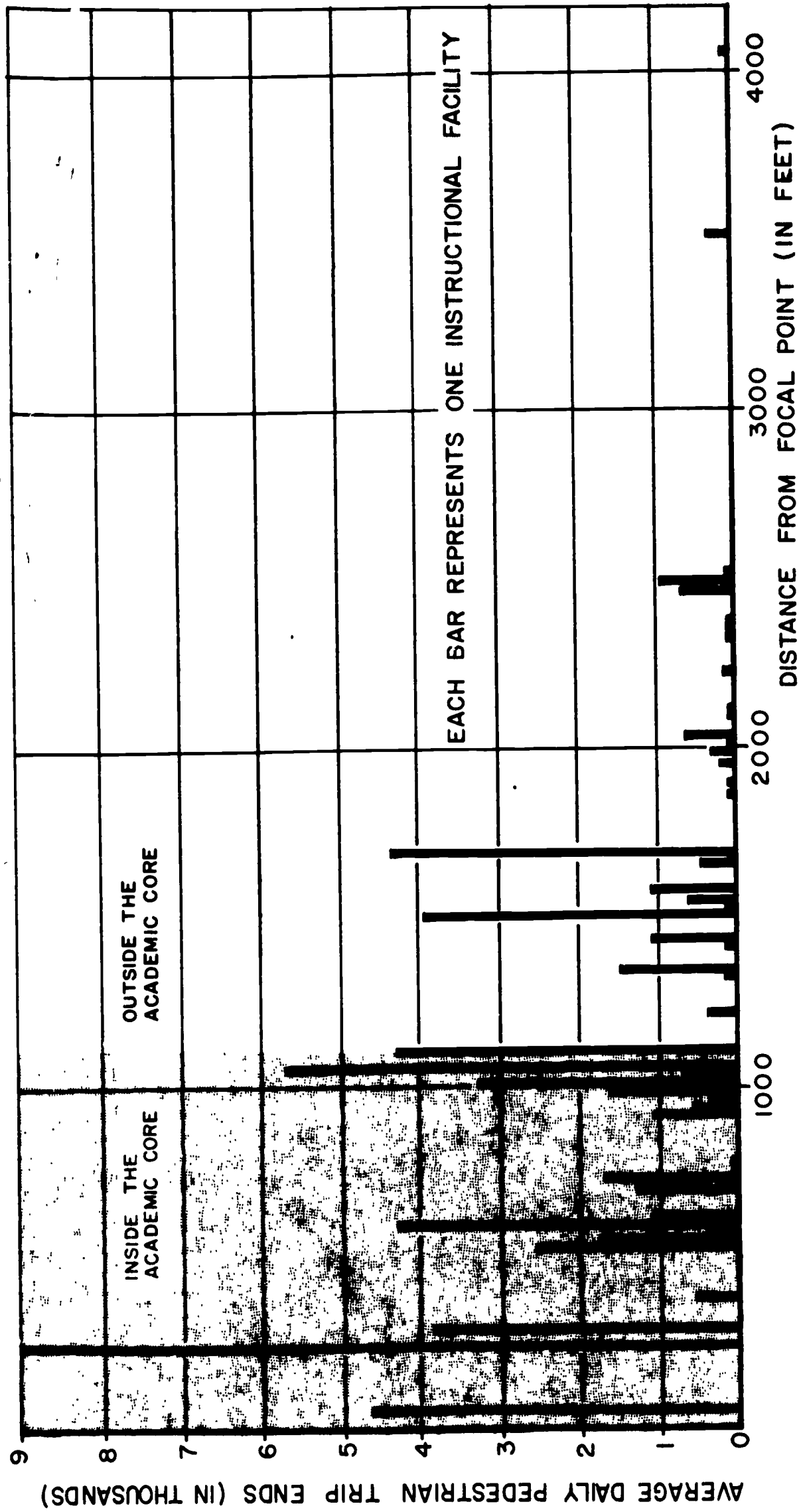
FIGURE 5 — AVERAGE DAILY PEDESTRIAN TRIP ENDS BY INSTRUCTIONAL FACILITY BY DISTANCE FROM THE FOCAL POINT, FALL 1967

Hall Laboratory building) and some infrequently used in-
structional facilities (e.g., Pierce Conservatory building
and the Aeronautical and Engineering Sciences building).

Pedestrian-Vehicle Conflicts

The existing network of pedestrian paths in the academic
zone was examined to determine the locations of pedestrian-
vehicle conflicts. Major conflicts take place on State
Street. Although fences and signals are provided to control
pedestrian crossings between the north and south campuses,
major conflicts still exist in a number of locations such
as in front of the Home Economics buildings and the Krannert
building. On the north campus, vehicular through traffic is
presently discouraged by blocking portions of some internal
streets. But a number of problematic points still remain
on Oval Drive, Memorial Mall, Stadium Mall, Purdue Mall and
south of the Hall of Music. Pedestrian-vehicle conflicts
are almost absent on the south campus. The railroad line
that passes through the academic zone does not seem to cause
any real problem. However, it is aesthetically incompatible
with the academic surrounding.

In the future, the volumes of pedestrian traffic will
tend to increase in proportion to the expected increase in
campus population. This calls for appropriate future actions
to minimize the pedestrian-vehicle conflicts pointed out
above and to maximize the efficiency of pedestrian circula-
tion in the academic zone. With this in mind, a number of

alternative circulation plans (in the academic zone) are developed in the next chapter. A number of recommendations concerning the future layout and use of different facilities in the academic zone are also given in Chapter IV.

Commuting to and from the Academic Zone

In this section, the campus population characteristics influencing commuting are first considered. Future commuting demands are then estimated.

Campus Population Characteristics Influencing Commuting

Data were collected on four characteristics of the campus population:

1. The size and the composition of the campus population (students, staff, and visitors).

2. The daytime population in the academic zone.

3. The student auto trips (home based).

4. The residential distribution of students on and around the campus.

The first, second, and fourth data items were obtained from the university records (11, 14-19, 21-23). The third was obtained by direct observation. In several cases, data from past years were used to ascertain whether or not noticeable trends existed.

Analyses were performed on these data to make possible the forecasting of future characteristics of campus population and hence future commuting demands. The results of a faculty questionnaire on policies affecting the development

of a university master plan was constantly used for guidance
in analysis and forecasting (14).*

Campus Population: Size and Composition. Three prin-
cipal campus population subgroups were considered: students,
staff, and visitors. For each, the existing size and com-
position are discussed and the future size and composition
are estimated.

Students. Students represent the greatest proportion of
the campus population. In the Fall of 1967, Purdue enrolled
about 23,370 students on the Lafayette campus. Like on many
other campuses, enrollment has greatly increased during the
past few years. Figure 6 shows the increase in the total
enrollment on the Lafayette campus during the period 1956-
1967 (11). In general, evidence indicates that a growing
percentage of the population seeks higher education and that
this percentage will most likely continue to increase in the
future (5). The enrollment on the Lafayette campus is thus
expected to grow. The question is not how far it will grow
but rather how far it should be allowed to grow. The problem
of an optimum enrollment size has repeatedly been raised
(10,12,13). Some believe that universities have already
exceeded the ranges of optimum enrollment. Others think more
students can still be accommodated. There appears to be no

---

* A summary of the results of this questionnaire appears in
  Appendix A.
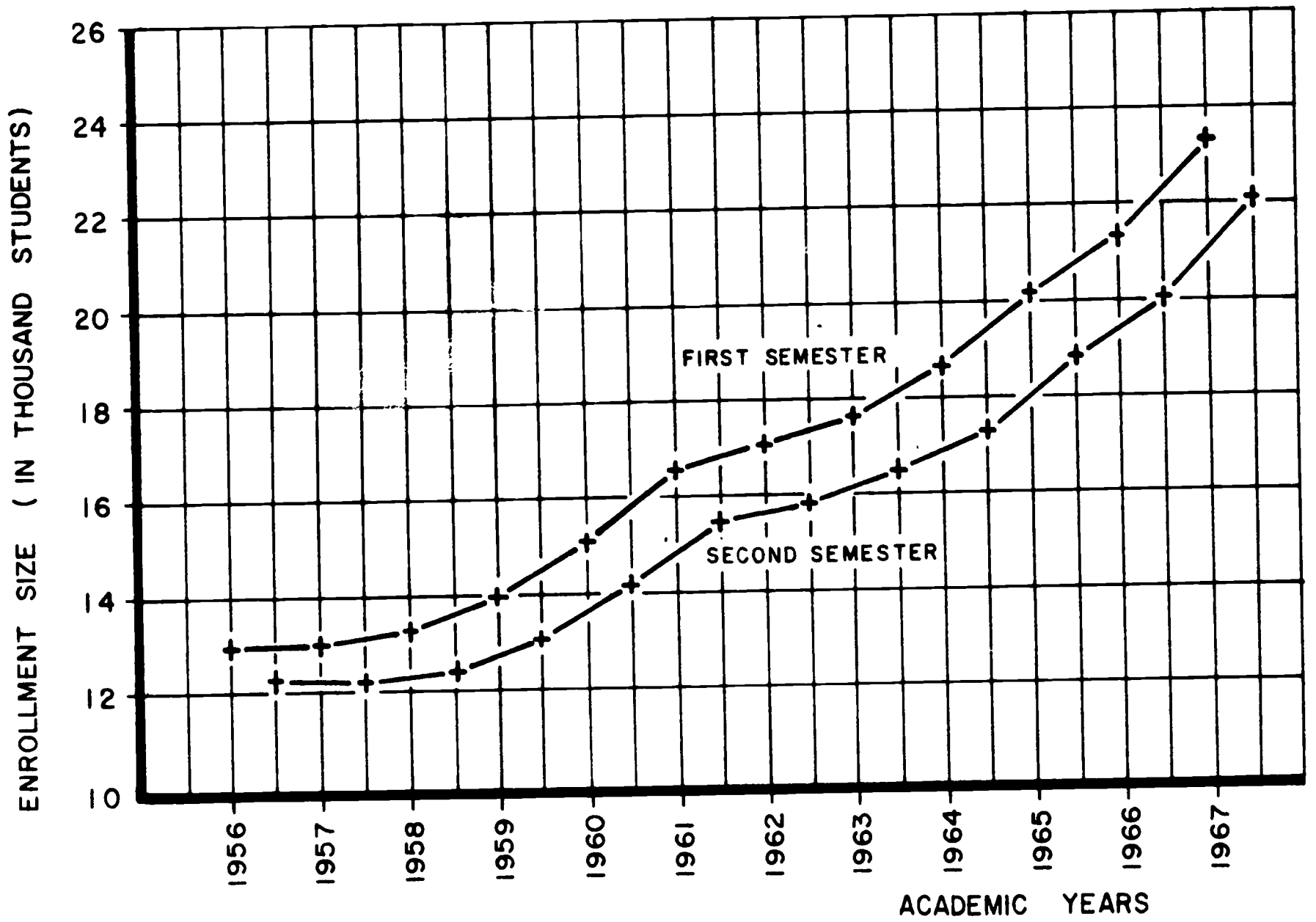
FIGURE 6 – ENROLLMENT ON THE LAFAYETTE CAMPUS, 1956–1967

general agreement as to what constitutes an optimum enroll-
ment size.

In this study, the ultimate future enrollment size was
determined on the basis of two criteria: (1) the opinions
of university faculty members, and (2) the capacity of the
existing academic zone. The faculty members seemed to reach
a concensus of opinion that enrollment on the campus should
be limited to 35,000 students (14). Assuming that the
present land area of the academic zone will remain virtually
unchanged in the future, and that the building standards
(average number of stories, average land coverage ratios,
and average gross built-up area per student) presently exist-
ing for the university (15) will be applied in the future,
it was found that the academic zone can easily accommodate
the ultimate enrollment agreed upon by the faculty. The ulti-
mate future enrollment on the Lafayette campus was thus taken
as 35,000 students.

From a campus transportation standpoint, two student
population characteristics were found to be important:
marital status and educational level (graduate or undergradu-
ate). Only these two characteristics were found to correlate
with the residential distribution of students and hence in-
fluence their choice of mode of travel (automobile versus
walking) to and from the academic zone.

In the Fall of 1967, about 52.5 percent of the graduate
students and about 10 percent of the undergraduate students
were married. For both subgroups (graduate and undergraduate),

these percentages remained almost unchanged during the period 1956-1967. For each subgroup, the future percentage of married students was assumed to remain the same as the average percentage of married students during the period 1956-1967; namely, 55 percent for the graduate students and 11 percent for the undergraduates.

To estimate the future total numbers of married students, the proportions of graduate and undergraduate students were examined. Since these proportions depend mainly on the University's educational philosophies, the opinions of faculty members were again consulted. Faculty members tended to agree that, in the future, the proportion of graduate students should be about 35 percent of the total enrollment (compared to about 23 percent in 1967) (14). Knowing that the future total enrollment is expected to reach 35,000 students, that 35 percent of these will be graduate students and that 55 percent of the graduate students and 11 percent of the undergraduates will be married, it was estimated that the number of married students will reach 9,240 students, or about 26.4 percent of the future ultimate enrollment.

Staff. Past trends indicate that the ratio of staff to students is almost entirely a matter of university policy. Therefore, estimates of the future number of full-time staff members were again based on the opinions of members of the faculty.

The results of the faculty questionnaire indicated a fairly consistent agreement on a future ratio of 0.27 full-time employees per student (14,16). Accordingly, it was estimated that, when ultimate enrollment is reached, the university will employ about 9,450 full-time staff members.

Visitors represented only a small percentage of the campus population. They are mainly attracted to the campus by special seminars, meetings, conferences, exhibits, and other periodic events conducted in the academic zone. As such, the future numbers of visitors are difficult to estimate. An approximate method, therefore, was used to estimate the future number of visitors parking in the academic zone by observing, for three different years, the ratio between the number of parking spaces (in the academic zone) used by visitors and by staff members, and by assuming that the average observed ratio (one parked visitor per 20 parked staff members) will remain almost constant in the future.

Daytime Population in the Academic Zone. The analysis of daytime population deals with the temporal distribution of the campus population in the academic zone. From a campus transportation standpoint, the interest focuses predominantly on periods of peak population concentrations in the academic zone since these peak periods produce parallel peak transportation demands. Besides, more specific aspects related to the concentration of students in the academic zone in

morning hours are also of interest in determining the expected loads on mass transportation systems that mig⸱⸱ be developed (as an alternative solution) to students' commuting needs.

Students. The numbers of students present in the academic zone at different hours on an average weekday were determined by two factors:

1. The university master schedule assigns the weekdays and the hours on which different courses are given. As such, it determines the total numbers of students using scheduled facilities in the academic zone at different hours.

2. The students' use of non-scheduled facilities such as libraries, cafeterias, and student offices determines the total numbers of students present in the academic zone while not attending classes.

Information on the space utilization of different scheduled facilities was obtained from university records in the form of student contact hours (available by day and hour for past semesters)(17). A student contact hour represents one student present in an instructional facility in one class period. By summing these student contact hours for all scheduled facilities in the academic zone by day by hour, the total number of students present in scheduled facilities at different hours was obtained for two Fall semesters (66/67 and 67/68) and two Spring semesters (66/67 and 67/68). The proportions these totals represented of the total

enrollment (for these semesters) were obtained. No signifi-
cant differences were observed between the results obtained
for these four semesters. Their average was used to repre-
sent the existing conditions. Figure 7 shows the average
percentages of students present in scheduled facilities at
different hours on an average weekday for the four semesters.

In the future, these observed percentages were also
assumed to apply. Since the master schedule presently used
by the university has initially been developed to optimize
the use of instructional facilities, any future deviation
from it would either mean class conflicts for more students
or an inefficient utilization of instructional facilities.
Accordingly, the existing percentages of students present
in scheduled facilities at different hours on an average week-
day (as determined by the master schedule) were assumed to
remain almost unchanged for the future.

To estimate the future proportions of students using
non-scheduled facilities, past and present data on the use
of different libraries and the meals served in different
cafeterias were obtained and analyzed (18,19). The propor-
tions of graduate students present in offices in the academic
zone were also estimated.

For libraries and cafeterias, two use characteristics
were considered: (1) the total numbers of daily users in
relation to the total enrollment, and (2) the proportions of
these daily users present in the facilities at different hours
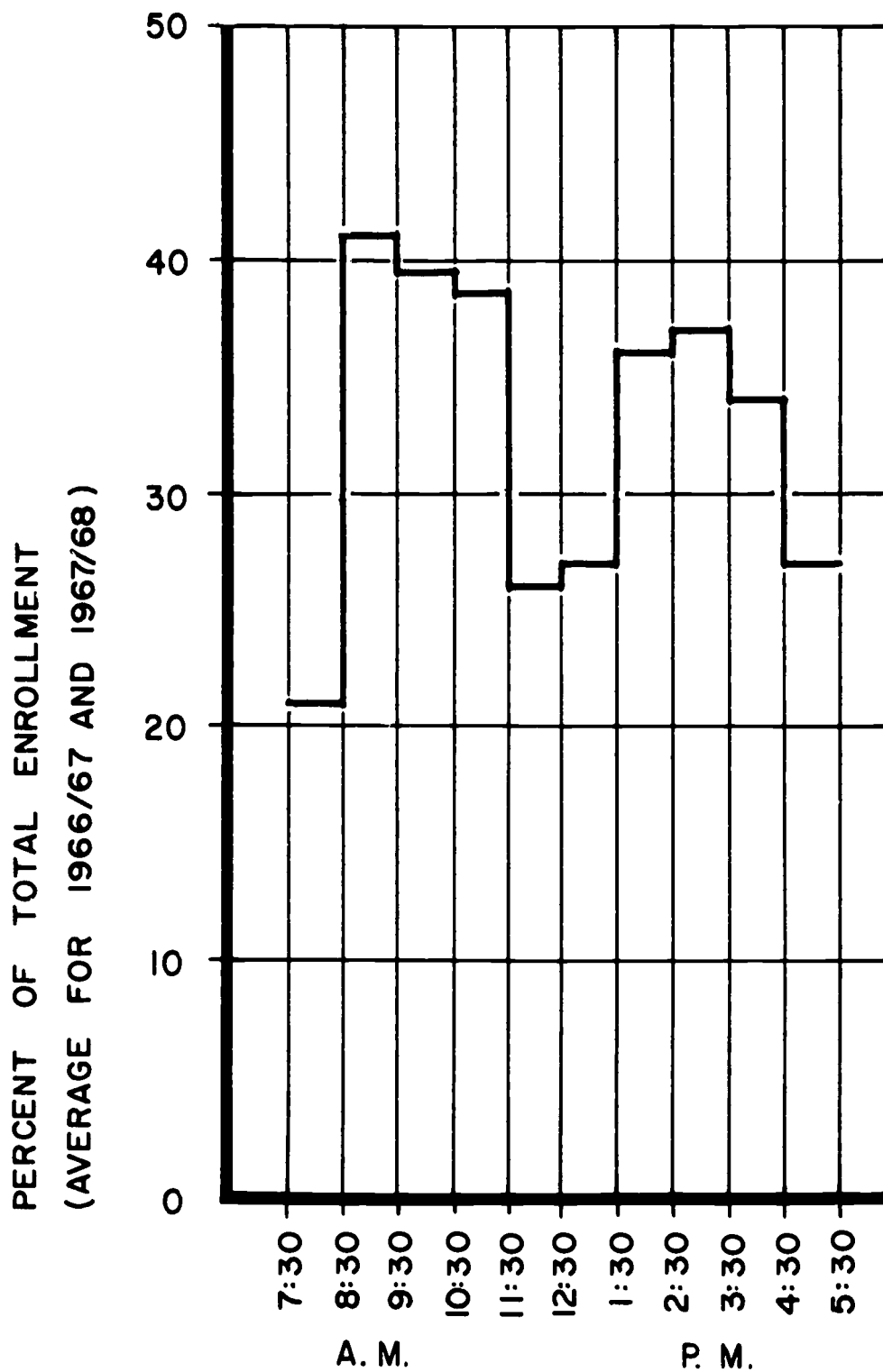
FIGURE 7 — PERCENTAGES OF STUDENTS IN SCHEDULED
FACILITIES IN THE ACADEMIC ZONE AT
DIFFERENT HOURS ON AN AVERAGE WEEKDAY

on an average weekday. For both types of facilities, stu-
dents represented the greatest majority of users. Having
established the past trends concerning the two above use
characteristics, the expected future use characteristics were
projected assuming that the same trends will continue. No
conclusive data could be obtained about the percentages of
graduate students present in their offices in the academic
zone at any one time. It was thus assumed that, for both
the present and the future, about 30 percent of the non-
staff graduate students are present in their offices on the
morning hours of an average weekday. The results of the
above outlined analyses are summarized in Table 1. The
table gives both the existing and the future percentages of
students using different facilities in the academic zone at
different hours on an average weekday.

Staff and Visitors. Because of the regular work hours
during which the majority of staff members are expected to
be present in the academic zone, the temporal distribution
of staff becomes virtually meaningless from the standpoint
of this study. Also, because visitors represent only a small
fraction of the campus population and because of the unpre-
dictable nature of their temporal concentrations in the
academic zone, their daytime population was not considered.
For these two groups (staff and visitors), the only estimates
of interest were those related to future parking demands
in the academic zone. These estimates are discussed later

Table 1. Students' Daytime Population in the Academic Zone - Existing and Future.

	Students using facilities in the academic zone expressed as percentages of the total enrollment					
	Existing (for an enrollment of 23,370 students in 1967)			Future (for an ultimate enrollment of 35,000 students)		
Hours	scheduled facilities	non-scheduled facilities	total in the academic zone	scheduled facilities	non-scheduled facilities	total in the academic zone
8:00 a.m.	21.0	5.0	26.0	21.0	6.0	27.0
9:00 a.m.	41.0	8.3	49.3	41.0	11.0	52.0
10:00 a.m.	39.5	11.3	50.8	39.5	14.5	54.0
11:00 a.m.	38.5	11.8	50.3	38.5	15.0	53.5
12:00 noon	26.0	12.3	38.3	26.0	15.0	41.0
1:00 p.m.	27.0	9.0	36.0	27.0	12.0	39.0
2:00 p.m.	36.0	10.0	46.0	36.0	13.0	49.0
3:00 p.m.	37.0	13.0	50.0	37.0	16.6	53.6
4:00 p.m.	34.0	11.2	45.2	34.0	15.0	49.0
5:00 p.m.	27.0	5.0	32.0	27.0	6.0	33.0

in this chapter.

Student Auto Trips. Student parking demand is generally
dependent on the ratio of home based student auto trips (auto
trips times occupancy rate) to student trips by all modes to
the academic zone. Conceptually, this ratio may be expected
to vary in relationship to income, automobile ownership,
trip length, availability of parking, and probably climate.
Under conditions of relative constant availability of parking
around the academic zone, trip length appears to be the main
factor influencing the student's decision to use or not to
use his automobile to commute from home to the academic zone.
It is conceivable that below a certain minimum trip length,
no student auto trips would be made and above a certain maxi-
mum trip length, all trips would be made by the automo-
bile. Between these minimum and maximum trip lengths, the
ratio of student auto trips to student trips by all modes
will vary according to trip length. The relationship between
trip length and the percentage of home based student auto
trips to the academic zone is particularly useful in student
parking demand forecasting models. However, to establish
such a relationship quantitatively, elaborate origin-
destination data would be needed.

In this study, and for the purpose of developing a stu-
dent parking demand forecasting model, a simplified technique
based on the observed relationship between trip length and
the number of home based student auto trips per student (to

all destinations including the academic zone) was used. The following is a brief discussion of the procedure applied to establish this relationship. The development of the forecasting model itself is discussed later in this chapter.

Home based student auto trips were examined in seventeen university residence facilities located at varying distances from the academic zone and housing different student subgroups (graduates, undergraduates, single, and married). For each of the examined facilities, the following data were obtained:

N = the total number of students living in the facility.

D = its distance (the actual walking path) from the focal point in the academic zone.

P_i = the number of automobiles parked at 6:00 a.m. in the parking spaces assigned to the facility (or obviously used by its residents).*

P_2 = the number of automobiles parked at 10:00 a.m. in the parking spaces assigned to the facility (or obviously used by its residents).

P_3 = the number of automobiles parked in the parking spaces assigned to married student apartments (in the facilities to which this item applies) at 8:30 a.m. on a day when the university was in session but classes were not.

---

* P_1 was not obtained for facilities housing married students.

K = average occupancy rate of automobiles leaving the facility.

The choice of 10:00 a.m. to observe the number of automobiles left in the parking lots (P_2) was made on the basis of previous parking studies on the Lafayette campus which indicated that the peak parking in and near the academic zone occurred at this hour (10:00 a.m.) (20).

For facilities housing single students, the total number of auto trips made from the facility to all destinations up to 10:00 a.m. = $P_1 - P_2$. The number of student auto trips per resident student (to all destinations) up to 10:00 a.m. = $\dfrac{K(P_1 - P_2)}{N}$.

For facilities housing married students, the number of student auto trips per resident (to all destinations) up to 10:00 a.m. = $\dfrac{K[(P_1 - P_2) - (P_1 - P_3)]}{N}$ or = $\dfrac{K(P_3 - P_2)}{N}$ where $P_1 - P_3$ is the number of auto trips performed by non-students (wives or other relatives), most probably work trips.

With this information obtained for each of the examined facilities, a relationship was established between the number of student auto trips per resident student (to all destinations) up to 10:00 a.m. and the trip length from the facility to the focal point in the academic zone.

The seventeen observations were fitted by the "least squares" method. The equation resulting was as follows:

$$Y = 1.045 \times 10^{-8} L^2 - 0.067 \quad \text{for } L \leq 10,105 \text{ and } \geq 2,523 \text{ feet}$$

where:

Y = the number of student auto trips per resident
student to all destinations up to 10:00 a.m. and,

L = the distance (in feet) between the residence and
the focal point in the academic zone (referred
to later as trip length).

Figure 8 shows the number of student auto trips per resident
student (to all destinations) up to 10:00 a.m. in relation
to trip length.

In this equation, the high coefficient of multiple de-
termination (R^2 = 0.93) confirmed the assumption that the
student's decision to use or not to use his automobile to the
academic zone is greatly influenced by the distance at which
he lives from the academic zone. As such, the observed
relationship is not expected to change significantly in the
future. It was thus used as a basis for developing a student
parking demand forecasting model. This was done on the
assumption that the relative parking availability in and near
the academic zone will remain virtually the same as now for
the future.

Residential Distribution of Students. Two character-
istics related to the residential distribution of students
were analyzed.

1. The proportions of students using different kinds of
residential facilities (university housing, fratern-
ity and sorority houses, cooperatives, and community
housing).
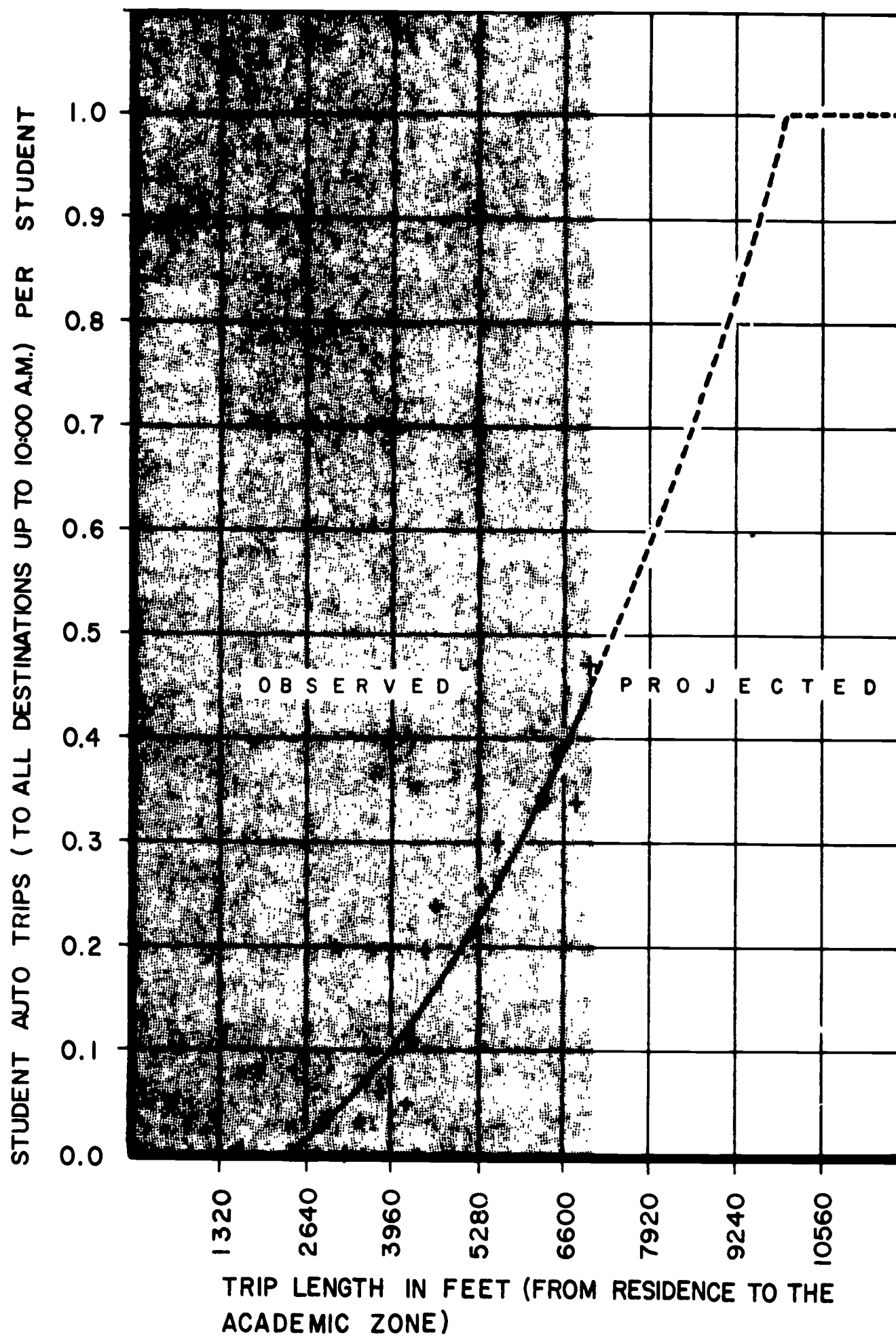
FIGURE 8 — STUDENT AUTO TRIPS PER STUDENT
BY TRIP LENGTH

2. The proportions of students living at different

distances from the academic zone.

The population of students was classified into six sub-
groups: graduate single men, graduate single women, graduate
married students, undergraduate single men, undergraduate
single women, and undergraduate married students. This
classification permits testing the hypotheses that sex, edu-
cational level, and marital status influence the student
residential distribution. It is also useful in forecasting
future changes in such residential distribution since the
prospective numbers of students in each of these subgroups
can easily be forecasted.

Students' Choice of Residential Facilities. In analyz-
ing the percentages of students using different kinds of
residential facilities, data on the entire population of stu-
dents for 1967/68 were used. Figure 9 shows the existing
university residential facilities, fraternities, sororities,
and cooperative houses. Data on the number of students
residing in these facilities and on the total enrollment by
student subgroups were obtained (21,11). The percentage of
students belonging to each subgroup and residing in each kind
of facility was established. Table 2 summarizes the findings
and Figure 10 illustrates them. Both educational level and
marital status show strong correlations with the choice of
the kind of housing facility. On the basis of these observed
percentages, the future percentages of students expected to

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968

FEET

N

☐ UNIVERSITY BUILDINGS
-- RAILROAD

▦ ACADEMIC ZONE

■ UNIVERSITY HOUSING

▦ FRATERNITIES & SORORITIES

■ COOPERATIVE HOUSES
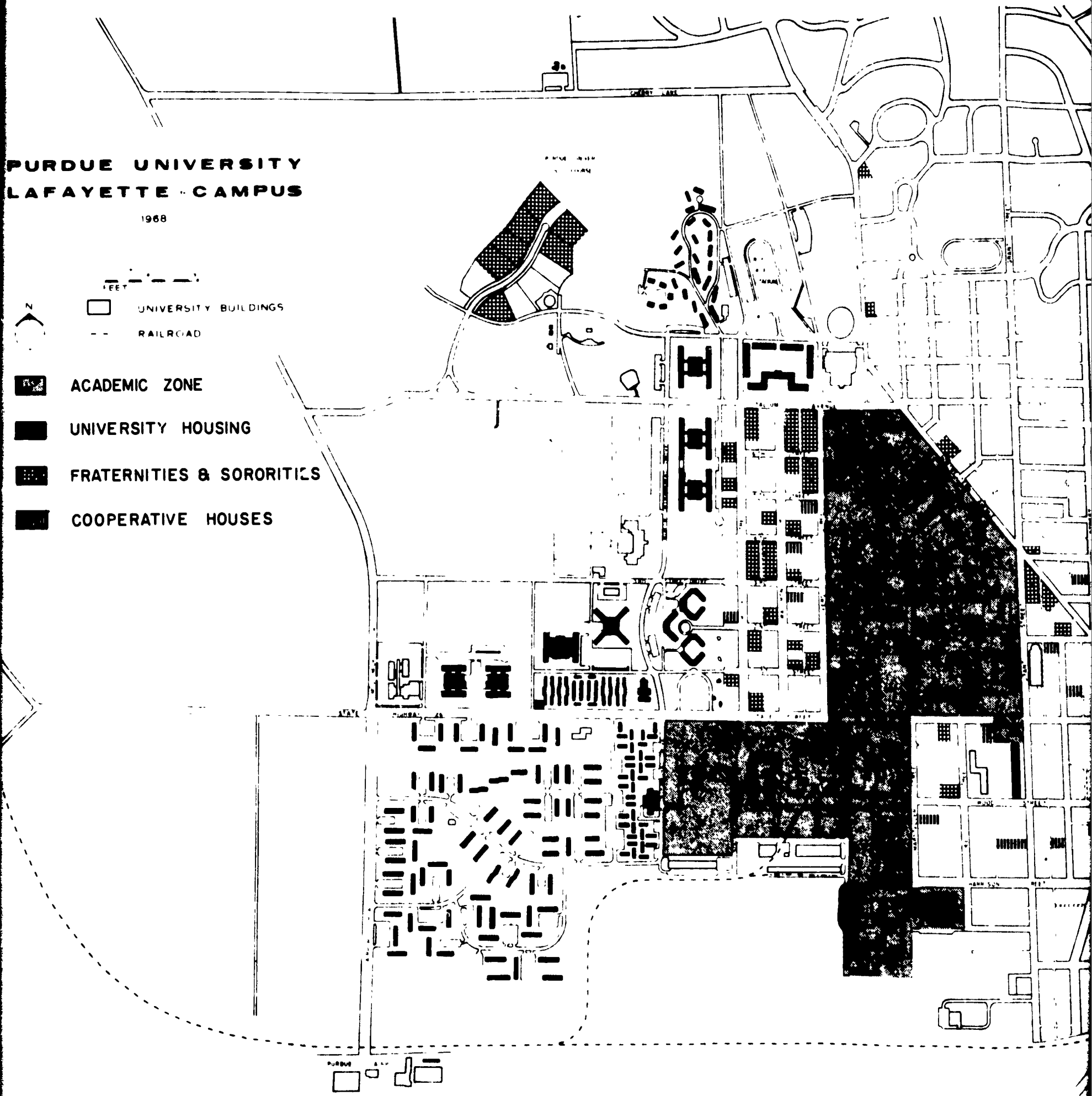
FIGURE 9 - EXISTING STUDENT HOUSING FACILITIES (OTHER THAN COMMUN

WABASH RIVER
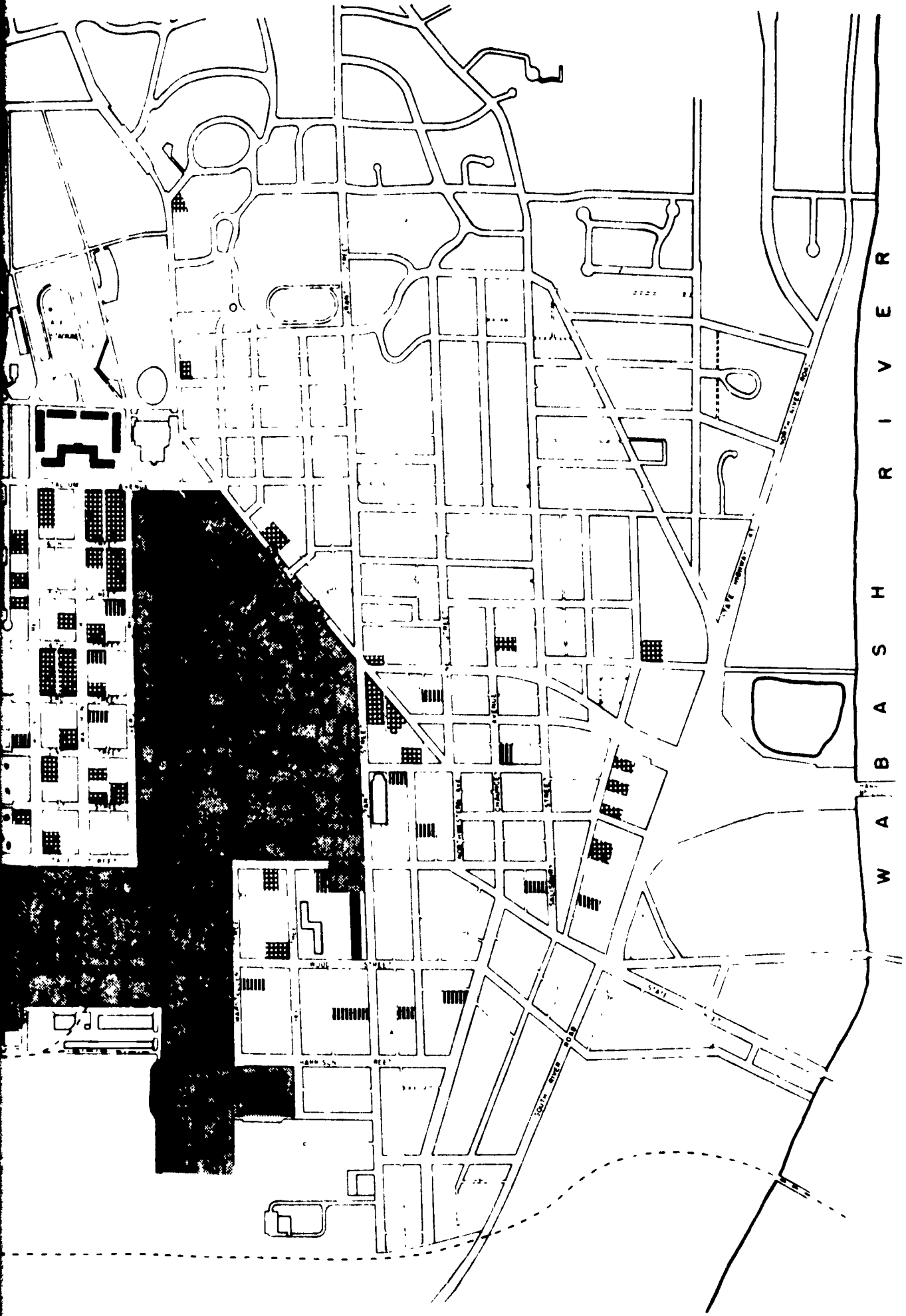
ES (OTHER THAN COMMUNITY HOUSING)

Table 2. Existing Distribution of Students in the Different Kinds of Available Housing Facilities.

Student Subgroups		University housing	Greek-letter Organizations	Cooperative houses	Community housing	Student enrollment (by student subgroups)	Percent of the total student enrollment
Graduate married	number	926	--	--	1,839	2,765	11.8
	percent*	33.5	--	--	66.5	100.0	
Undergraduate married	number	841	--	--	991	1,832	7.8
	percent	46.0	--	--	54.0	100.0	
Graduate single men	number	450	--	--	1,503	1,953	8.4
	percent	23.0	--	--	77.0	100.0	
Graduate single women	number	200	--	--	353	553	2.4
	percent	36.0	--	--	64.0	100.0	
Undergraduate single men	number	5,309	2,154	319	3,373	11,155	47.7
	percent	47.6	19.3	2.9	30.2	100.0	
Undergraduate single women	number	2,953	906	141	1,112	5,112	21.9
	percent	57.8	17.7	2.8	21.7	100.0	
Total Students	number	10,679	3,060	460	9,171	23,370	100.0
	percent	46.0	13.3	2.0	39.0	100.0	

Numbers and percentages of students living in different kinds of housing facilities

* Percentages of the total enrollment in the subgroup.
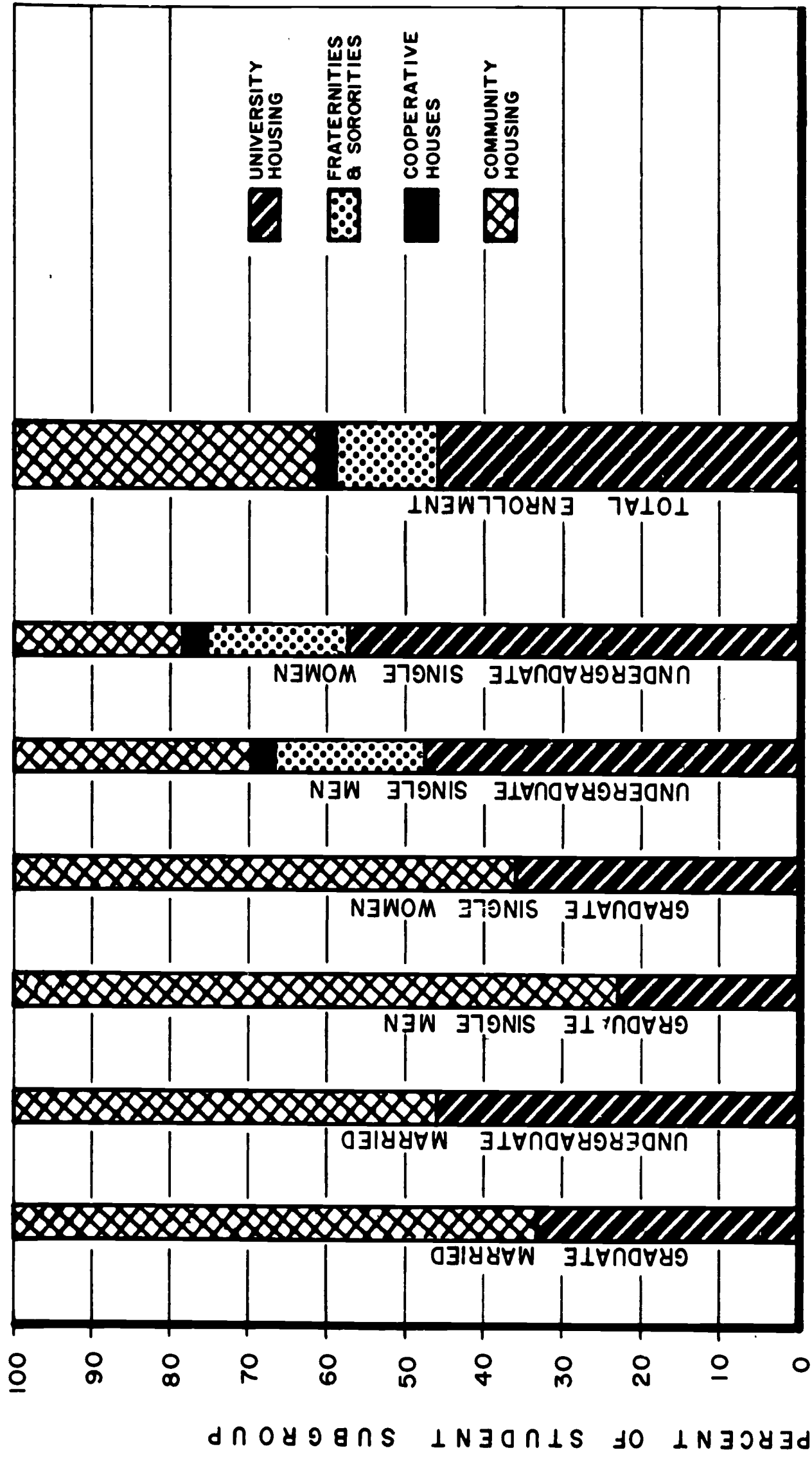
FIGURE 10 – PERCENTAGES OF STUDENTS LIVING IN DIFFERENT KINDS OF
HOUSING FACILITIES BY STUDENT SUBGROUP, FALL 1967

live in different kinds of residential facilities were esti-
mated. Both university housing policy and the students po-
tential demand on university housing were considered. The
results of the faculty questionnaire indicated an envisaged
increase in the proportions of students housed in university
housing facilities (14). During the period 1963-1967 stu-
dents' demand on university housing facilities tended to
increase (22). These facilities appear to offer economic
advantages (in rents, maintenance, and proximity to the aca-
demic zone) that are difficult to match in community owned
housing facilities.

Based on the opinions of faculty members and on the ob-
served trends of student demand on university housing facil-
ities, it was estimated that about 55 percent of the under-
graduate single students, 40 percent of the graduate single
students, and 40 percent of the married students will be
accommodated in university housing facilities in the future.

The Spatial Distribution of Student Residences. As
noted previously, the number of student auto trips is highly
correlated with the distances at which students live from
the academic zone. As such, the spatial distribution of
student residences becomes meaningful from the standpoint of
campus transportation planning. The following is an analysis
of the spatial distribution of the student residences around
the academic zone. The primary purpose of the analysis is
to examine the existing and estimate the future proportions

of students living at different distances from the academic zone.

Because the composition of the population of students is expected to change in the future, the analysis of the spatial distribution of the student residences should test whether or not future changes in the student population composition would cause changes in the proportions of students living at different distances from the academic zone. In other words, the analysis should test, for each student subgroup (graduates, undergraduates, single, married...etc.), whether or not the proportions of students living at different distances from the academic zone are significantly different from those of other subgroups. Subgroups that show significant differences should, then, be analyzed separately while others can be lumped together. This analysis was performed in two steps:

1. A number of relevant student population subgroups were first tested, in pairs, for significance of differences in the mean distances at which students live from the academic zone and in the variances of these distances from the means. Statistically, subgroups, which have significantly different means and variances should also have significantly different proportions of students living at different distances from the academic zone. Moreover, testing for means and variances is much more reliable

and requires relatively smaller sample sizes. By
this step, therefore, significantly different sub-
groups were identified.

2. For each of the identified subgroups, the existing
   percentages of students living at different dis-
   tances from the academic zone were statistically
   estimated and the future percentages then forecasted.

To identify student population subgroups living at sig-
nificantly different distances from the academic zone (in
terms of means and varia..ces) a pilot study on a small sample
of students was first undertaken. The preliminary results of
this pilot study suggested further testing of five student
subgroups: graduate single, graduate married, undergraduate
single men, undergraduate single women, and undergraduate
married students. The sizes of statistically representative
samples of students of these five subgroups were also de-
termined on the basis of this pilot study. From university
records, the data obtained gave the student's status (male,
or female, single or married, graduate or undergraduate)
and his local address (23). Student addresses were grouped
in distance classes (concentric rings around the focal point)
with an interval of 0.25 miles. Residences located at dis-
tances over four miles from the focal point were not included
to avoid distortion of results.

For each of the five subgroups, the means and variances
(of the distances of residences from the focal point) were

obtained and tested, in pairs, for significance of differ-
ence. Both the mean and variance of the distance at which
single students live (both graduate and undergraduates) were
found to be significantly different (on the 0.05 $\propto$ level)
from those for married students (both graduates and under-
graduates). No other significant differences were found.
Accordingly, for each of these two subgroups, the existing
proportions of students living at different distances from
the academic zone were statistically estimated. The student
addresses were grouped in distance classes with an interval
of 0.50 miles (actual walking distance zones). Figure 11
shows the boundaries of these zones. The range of distances
covered in the analysis and the class interval used were set
on the basis of the observed numbers of student auto trips
discussed earlier.

The size of a statistically representative sample of
students was set according to maximum allowable estimation
errors of $\pm$ 2 pe   nt for single students and $\pm$ 3 percent
for married students. By plotting the student addresses
(in Spring 1967) on a map, the numbers (and thus the
percentages) of residences falling in each distance zone were
obtained. The results were tabulated by student subgroup,
by distance zone, and by kind of residence facility. Table
3 shows the existing percentates of students living in dif-
ferent kinds of housing facilities at different distances
from the academic zone for single students and married stu-
dents. Figure 12 shows the existing cumulative "less than"

Lafayette and West Lafayette

Indiana

1 9 6 8
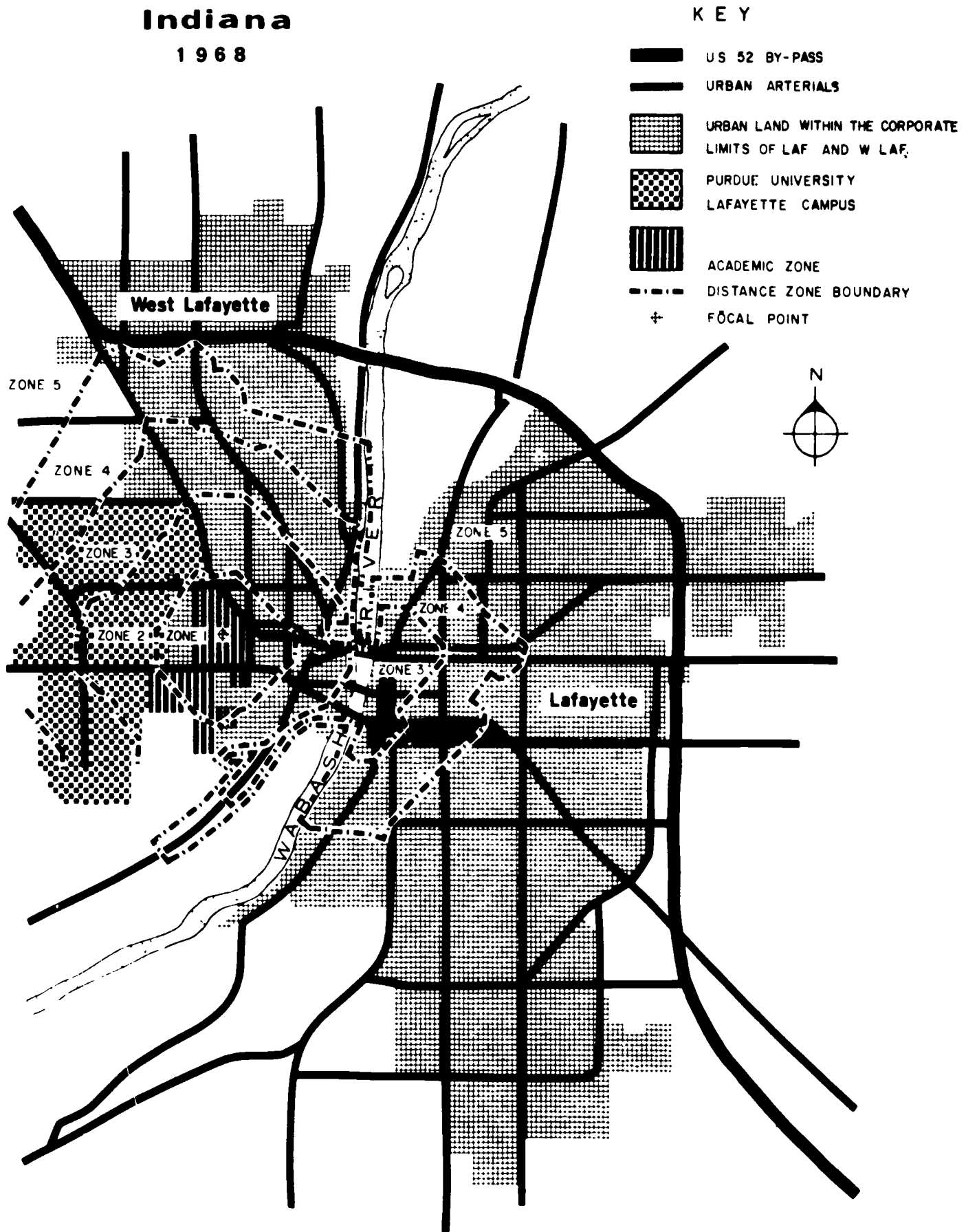
FIGURE II – RESIDENTIAL DISTRIBUTION OF STUDENTS –
DISTANCE ZONES

Table 3. Existing Percentages of Students Living in Different Kinds of Housing Facilities at Different Distances from the Academic Zone.

| Distance from the academic zone (in miles) | Percentages of students living in different kinds of housing facilities | | | | | | | |
| | Single students | | | | | Married students | | |
	University housing	Greek-letter organizations	Cooperative houses	Community housing	Total	University housing	Community housing	Total
.01 to .50	15.0	11.0	2.0	11.0	39.0	--	8.0	8.0
.51 to 1.00	32.5	3.0	0.5	3.0	39.0	22.5	7.5	30.0
1.01 to 1.50	--	2.0	--	4.5	6.5	15.5	3.0	18.5
1.51 to 2.00	--	--	--	2.5	2.5	--	4.0	4.0
2.01 or more	--	--	--	13.0	13.0	--	39.5	39.5
Total	47.5	16.0	2.5	34.0	100.0	38.0	62.0	100.0
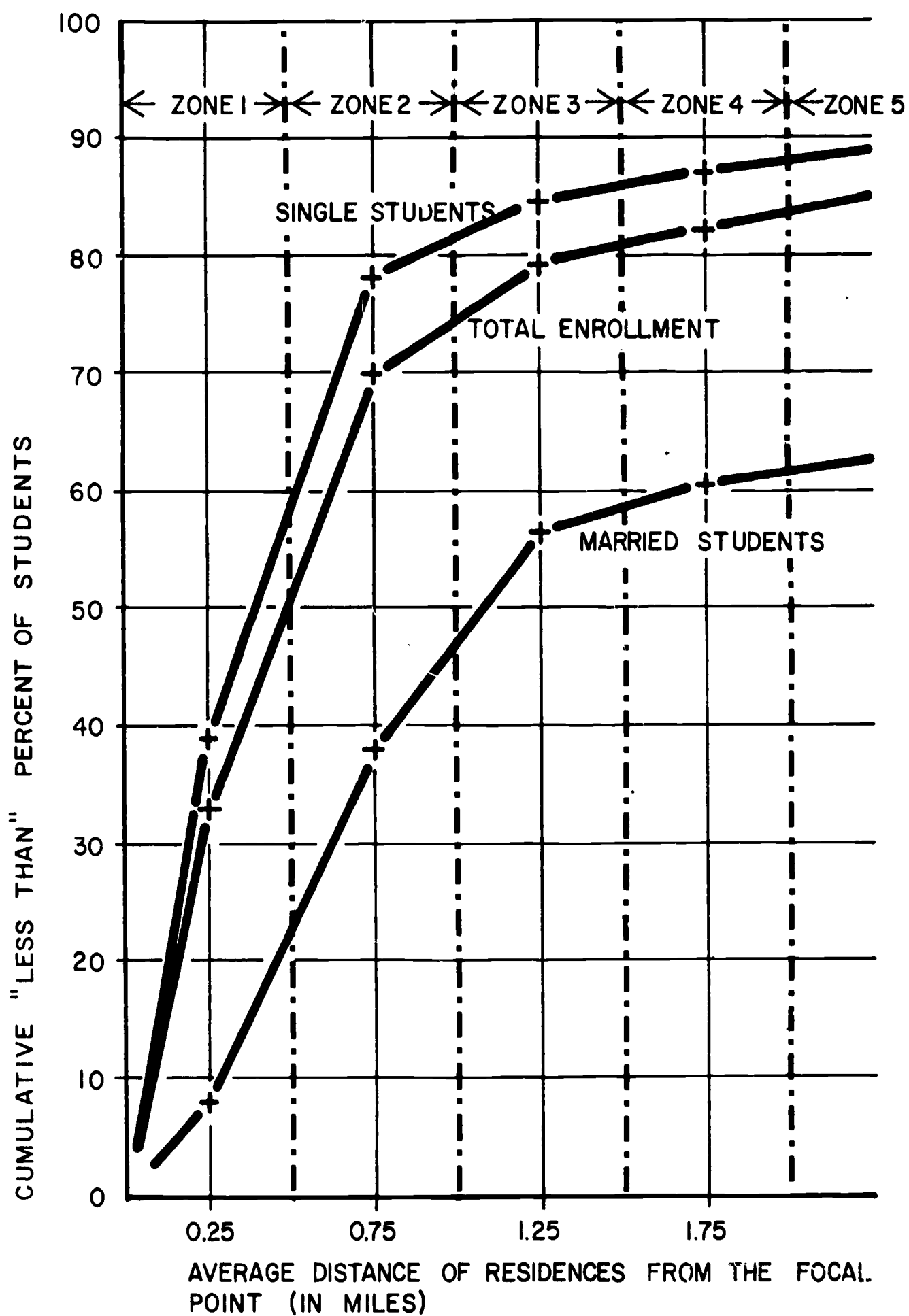
FIGURE 12 — PERCENTAGES OF STUDENTS LIVING AT
DIFFERENT DISTANCES FROM THE
ACADEMIC ZONE, SPRING 1967

proportions of students living at different distances from
the academic zone for single students, married students, and
all students.

About 13 percent of the single students and about 39.5
percent of the married students live at distances over two
miles. As expected, the percentage of single students liv-
ing distant from the academic zone is much less than that
of the married students. Single students neither have the
need for suburban spacious living nor are willing to sacri-
fice the proximity to the intense social interactions on
and around the academic zone. High concentrations of both
single and married students occur within one mile from the
academic zone. This is obviously due to the fact that all
university housing facilities are located within this range
of distance. About 46 percent of the students living in
this range live in university facilities. The remaining
proportion indicates an undebatable trend of students to
live close to the academic zone even if they live in non-
university facilities.

These findings and observations provide the basis for
estimating the future distribution of student residences.
This was estimated on the basis of three main residential
aspects:

    1. The estimates of future numbers of students living
        in different kinds of housing facilities.

2. The expected future locations of the different
   kinds of housing facilities.

3. The existing proportions of students living at
   different distances from the academic zone.

The first and third aspects have already been discussed.
The following is a discussion of the second aspect; the ex-
pected locations of the different kinds of housing facili-
ties.

Future Greek-letter organizations and cooperative houses
are expected to be provided at approximately their present
distances from the academic zone. Additional community
housing facilities are apt to be provided at distances be-
tween 1.5 and 2.5 miles. Little room for expansion at closer
distances is available for these facilities. The future
locations of university housing facilities are subject to
different probable policies. A number of possible alterna-
tive layouts of future university housing facilities (based
on the existing standards of land coverage and building
heights) were developed and examined to determine which would
provide maximum future advantages. The layout in which the
future housing facilities were most closely located in rela-
tion to the academic zone and which still provided flexibil-
ity in future land uses was chosen. Figure 13 shows the as-
sumed locations of future university housing facilities.
Accordingly, the future proportions of students living at
different distances from the academic zone were estimated.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968

```
—  —  —  —
    FEET
   [  ]  UNIVERSITY BUILDINGS
   - -  RAILROAD
```

N

ACADEMIC ZONE

GRADUATE HOUSES

UNDERGRADUATE RESIDENCE HALLS

MARRIED STUDENT APARTMENTS

S OF FUTURE HOUSING FACILITIES

FUTURE HOUSING UNITS EXPRESSED AS PER-CENTS OF THE NET FUTURE REQUIREMENTS.		
FOR GRADUATE SINGLE STUDENTS	FOR UNDERGRADUATE SINGLE STUDENTS	FOR MARRIED STUDENTS
100	10	—
—	90	20
—	—	50
—	—	30
100	100	100

13 — PROBABLE LOCATIONS OF FUTURE UNIVERSITY HOUSING FACILITIES
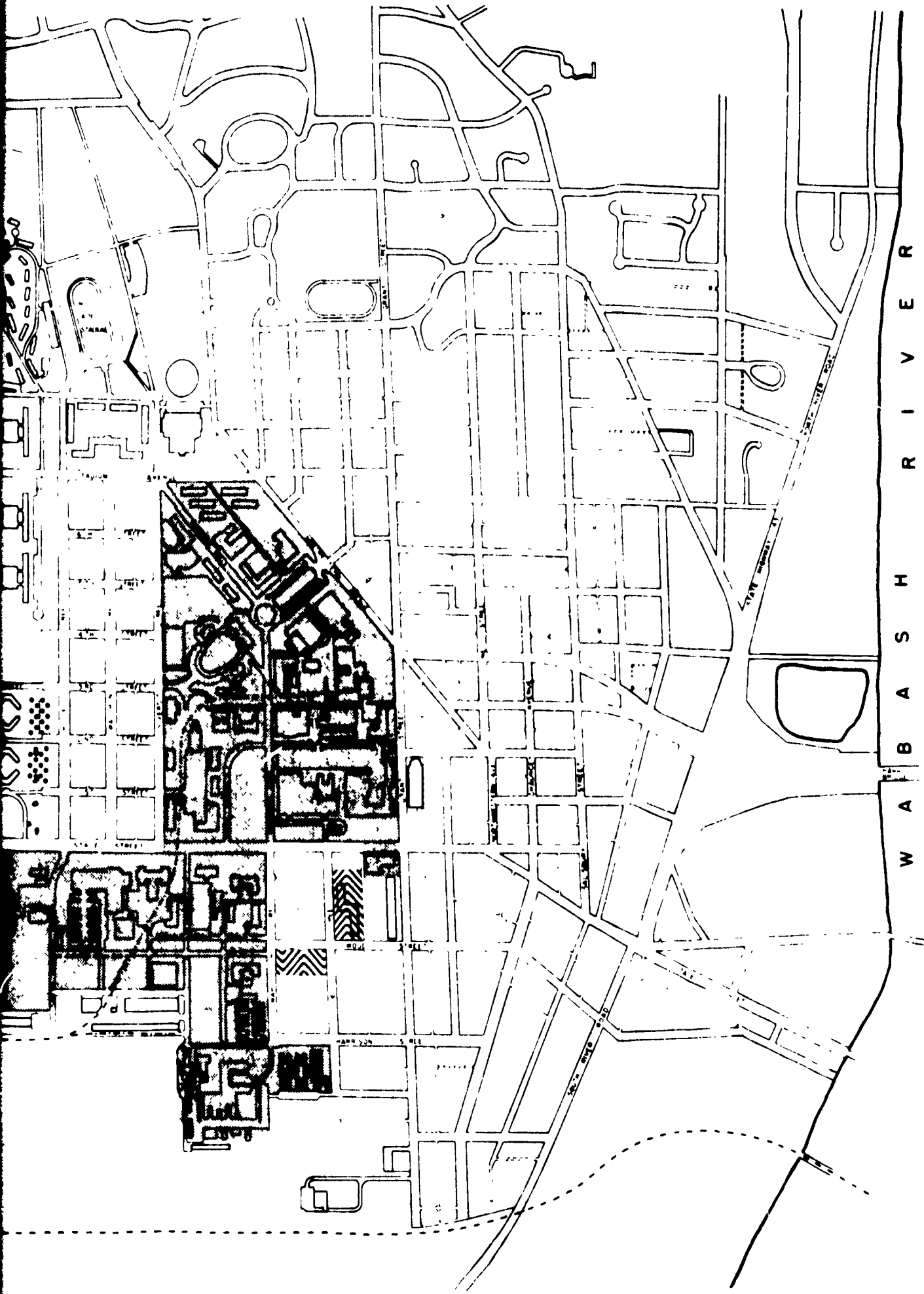
ERSITY HOUSING FACILITIES

Table 4 shows the estimated future percentages of students living in different kinds of housing facilities at different distances from the academic zone.

Future Commuting Demands

Four campus population characteristics influencing present and future trip productions and trip modes to and from the academic zone have been discussed. In this section, the future demand for commuting to and from the academic zone will be estimated. The magnitude of this demand depends on the size and composition of the campus population and the daytime population in the academic zone. The choice of transportation modes in commuting depends on the patterns of student auto trip productions, on the residential distribution of students, and on the available alternative modes of transportation. Three alternative modes of commuting will be examined: (1) by automobile from residence to parking facilities around the academic zone, (2) by buses either from residence or from remote parking facilities to the academic zone, and (3) on foot.

The importance of considering traffic volumes on the street network surrounding the academic zone and caused by commuting is recognized. In this study, however, the discussion of this aspect is limited to a subjective evaluation of the effects on traffic volumes on the network of some alternative locations, types, and capacities of future university parking facilities in and around the academic zone. To

Table 4. Estimated Future Percentages of Students Living in Different Kinds of Housing Facilities at Different Distances from the Academic Zone.

Percentages of students living in different kinds of housing facilities

Distance from the academic zone (in miles)	Single students					Married students		
	University housing	Greek-letter organizations	Cooperative houses	Community housing	Total	University housing	Community housing	Total
.01 to .50	14.0	9.6	1.7	7.5	32.8	--	4.0	4.0
.51 to 1.00	37.7	3.4	0.8	2.8	44.7	14.8	7.0	21.8
1.01 to 1.50	--	3.0	--	4.0	7.0	18.4	3.0	21.4
1.51 to 2.00	--	--	--	2.5	2.5	6.8	6.0	12.8
2.01 or more	--	--	--	13.0	13.0	--	40.0	40.0
Total	51.7	16.0	2.5	29.8	100.0	40.0	60.0	100.0

obtain reliable estimates of future average traffic volumes
on the street network surrounding the academic zone would re-
quire a multiplicity of other input data (other than future
locations, types, and capacities of university parking fac-
ilities) that are beyond the scope of this study.

Future Parking Demands. In 1968, a total number of about
5630 off-street parking spaces (in and around the academic
zone) were provided and operated by the university. The ma-
jority of these spaces are provided for full-time staff mem-
bers. A relatively limited number of spaces are assigned
to commuter students and visitors. Besides, on-street free
parking is available around the academic zone. For the fu-
ture, the relative availability of parking was assumed to re-
main virtually unchanged. The future parking demands were
estimated accordingly. Demands by students, staff, and
visitors were estimated separately.

Students. The relationship between trip length (from
residence to the academic zone) and the number of student
auto trips per resident student (to all destinations) up to
10:00 a.m. was established earlier. Based on this relation-
ship, a students' parking demand forecasting model was de-
veloped. The total number of student automobiles actually
parked around the academic zone at 10:00 a.m. on an average
week day was assumed representative of the student parking

demand.*

Let:

i = zones of different ranges of trip lengths where $i = 1, 2, ..., 5$ (see Figure 11).

A_i = total number of student auto trips from zone i to all destinations up to 10:00 a.m.

Z_i = total number of student auto trips from zone i to the academic zone up to 10:00 a.m.

M_i = total number of student trips by all modes from zone i to the academic zone up to 10:00 a.m.

L_i = average trip length from residences in zone i to the focal point in the academic zone (in feet).

N_i = total number of students living in zone i.

K_i = average auto occupancy rate for trips from residences in zone i to the academic zone.**

C = percent of students living in zone i and expected to be present in the academic zone up to 10:00 a.m. "C" is assumed constant for all values of i since the master schedule of the university on the basis of which student class schedules are determined

---

* The area referred to as "around the academic zone" is that used in a study on future traffic facilities for the Lafayette campus and includes three rows of blocks around the academic zone (20).

** For married students, average auto occupancy was estimated to be 1.1 students per auto for all zones. For single students, average auto occupancy was estimated to be 2.5 for zone 2 and was accordingly assumed to be 2.2, 1.8, and 1.3 students per auto for zones 3, 4 and 5 respectively.

(and hence the hours at which they should be
present in the academic zone) is not "biased"
by marital status (and thus not "biased" by dis-
tance of residence).

T_i = number of student auto trips to the academic zone
per student trip by all modes to the academic
zone up to 10:00 a.m.

therefore

$$T_i = \frac{Z_i}{M_i}$$

In terms of A_i and N_i, this can be expressed as follows:

$$T_i = \frac{A_i}{N_i} \times \frac{\frac{Z_i}{A_i}}{\frac{M_i}{N_i}}$$

but $\frac{A_i}{N_i} = Y_i$ = number of sutdent auto trips per resident stu-
dent (in zone i) to all destinations up to
10:00 a.m.

therefore

$$T_i = Y_i \cdot q_i$$

where

$$q_i = \frac{\frac{Z_i}{A_i}}{\frac{M_i}{N_i}} = \frac{\frac{Z_i}{M_i}}{\frac{A_i}{N_i}}$$

It can be shown mathematically that if Z_i is equal to
A_i, q is independent of i. In this case, it can be safely

assumed that $Z_i = A_i$ since the great majority of student auto trips up to 10:00 a.m. are expected to end around the academic zone. Therefore, q is assumed constant for all values of i.

If P_s is the total number of student automobiles parked around the academic zone at 10:00 a.m. on an average weekday, then

$$P_s = \sum_{i=1}^{5} C \cdot N_i \cdot \frac{T_i}{K_i} = \sum_{i=1}^{5} C \cdot N_i \cdot \frac{Y_i \times q}{K_i}$$

or

$$P_s = C \cdot q \cdot \sum_{i=1}^{5} \frac{N_i \, Y_i}{K_i}$$

but Y_i has previously been shown to have the following value:

$$Y_i = 1.045 \times 10^{-8} \, L^2 - 0.067 \quad \text{for } L \leq 10,105 \\ \text{and} \geq 2,523 \text{ feet}$$

In this model, the future values of the independent variables (C, N_i, Y_i) were estimated earlier in the discussion of the population characteristics influencing commuting. "C" was estimated from the analysis of the student daytime population in the academic zone, N_i was estimated from the analysis of the student residential distribution, and Y_i was established by direct observation. Values of K_i for zone 2 (for single and married students) were estimated by direct observation while those for zones 3 through 5 were subjectively assumed accordingly.

To establish the value of the constant q in this model, the result of an actual count of student automobiles parked around the academic zone at 10:00 a.m. in the Spring of 1968 (1650 automobiles) was used for calibration (20). The value of q was found to be equal to 0.7. The accuracy of the model was then tested by comparing the total number of student automobiles parked around the academic zone at 10:00 a.m. in the Spring of 1962 as obtained by an actual count and as replicated by the model. The actual count in 1962 was 1150 automobiles while the total as replicated by the model was 1077 automobiles. The error is acceptable for the purpose of this study.

Accordingly, for the ultimate enrollment, the future student peak parking demand (at 10:00 a.m.) is estimated to be about 3,316 parking spaces. This estimate was increased to 3,685 parking spaces since only 90 percent of available parking spaces can be used efficiently during periods of peak parking demand. Of these, about 600 parking spaces are expected to be required by students living in university housing facilities (married student residents, McCutcheon Hall, etc.).

Staff and Visitors. At the present time, the university operates sufficient parking for all full-time staff members. It was assumed that this policy will remain unchanged in the future. To estimate future staff parking demand, a relationship was established, on the basis of data obtained

from university records for the years 1963 through 1967, between the number of staff parking spaces provided by the university in the academic zone and the total number of full-time staff members working there (20). Knowing that the number of staff parking spaces provided in these past years by the university in the academic zone proved adequate, the established relationship was thus used to estimate the future staff parking demand.

In establishing this relationship, the ratio of the number of full-time staff members working in the academic zone to the total number of full-time staff members (on the whole campus) was determined for 1962 and assumed constant in the future.* Figure 14 shows the observed and projected relationship between the number of staff parking spaces provided by the university in the academic zone and the number of full-time staff members working there. In this figure, the observations obtained for the five past years (1963 through 1967) were fitted by using the "least squares" method. The resulting straight line relationship was:

$$P_F = 1.17\ F_a - 2958.7 \quad (R^2 = 0.96)$$

where P_F = number of staff parking spaces provided in the academic zone (including an allowance of 10 percent for peak hour vacancies), and

F_a = number of full-time staff members working in the academic zone.

---

* Data were not available for any other years.
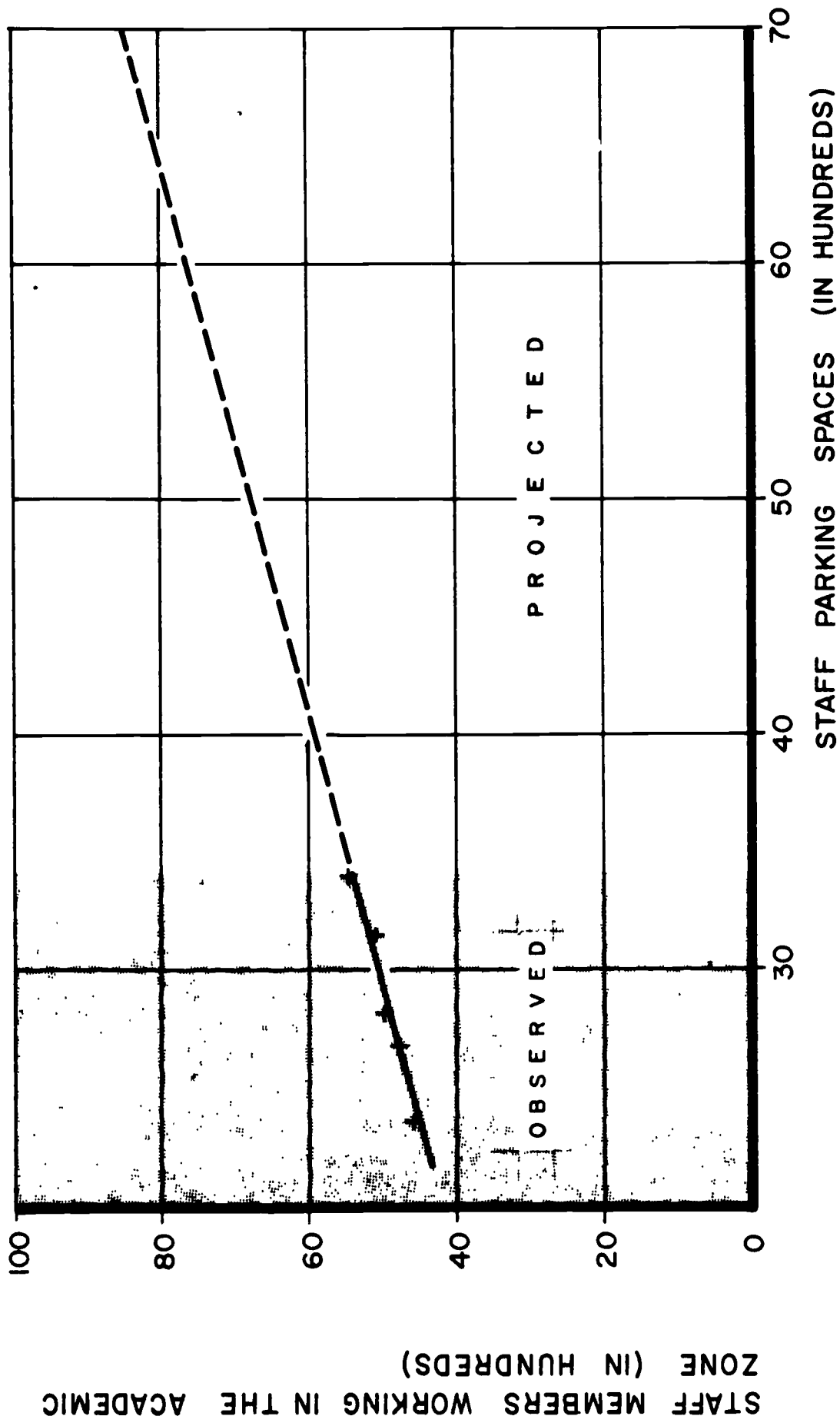
FIGURE 14 – NUMBER OF STAFF PARKING SPACES PROVIDED BY THE
UNIVERSITY PER STAFF MEMBER WORKING IN THE
ACADEMIC ZONE, 1963 – 1967

It is recognized that this formula has the limitation of being based on a relatively small number of observations. However, for the purpose of estimating future staff parking demand, the formula gives reasonab'e accuracy.   For the ultimate campus population, about 8,210 staff members are expected to be working in the academic zone (0.87 of the total number of staff members on the campus).   Future staff parking demand at ultimate enrollment was thus estimated (on the basis of the established relationship) to be about 6,650 parking spaces.

In estimating future visitor parking demand, the ratio of the number of parking spaces (in the academic zone) used by visitors to that used by staff members was observed for 1965 through 1967.   The ratio was found to be about 0.05. It was assumed that, in the future, the university will still provide visitor parking for about 0.05 of the staff parking demand.   Thus, the ultimate future visitor parking demand was estimated to be about 330 spaces.

Future Provision of Bus Systems.   The future provision of bus systems as an alternative mode of commuting to the academic zone was considered.   Buses, if used, should be basically planned to meet student commuting demands.   Staff and visitors are not expected to use the system in the periods of peak student loads.   Buses can be operated from remote parking facilities and/or university housing facilities to the academic zone and vice versa.   They can thus

substitute for part of the need for parking around the aca-
demic zone and/or commuting by automobile from university
housing facilities. As such, the student loads expected on
a bus system around a given time depend on the number of
student auto trips expected to be made to the academic zone
around the same time.

The expected future student load on a bus system was
estimated as follows. Of the existing on-street free park-
ing spaces around the academic zone, about 1000 spaces were
assumed to remain used in the future. Analysis of the day-
time population shows that about 27 percent of the student
population are expected to be present in the academic zone at
7:30 a.m. These students are also expected to make about
1658 auto trips to the academic zone shortly before this time.
Due to the favorable locations of the parking spaces around the
academic zone, these will probably be almost entirely oc-
cupied by 7:30 a.m. Remote parking facilities and the bus
system (if this combination is provided) will then start to
accommodate the overflow. But at 8:30 a.m., 52 percent of
the students are expected to be present in the academic zone.
If it is assumed that not more than 2 percent of the student
population return to their residences after the 7:30 a.m.
class, then not more than 27 percent of the student popula-
tion will have to commute to the academic zone between 7:30
and 8:30 a.m. These will have little choice but to use

remote parking facilities and the bus system or to walk.
As such, these constitute the probable peak student load on
the system since analysis of other daytime populations does
not suggest the probability of higher peaks at any one time
after 8:30 a.m.*

Accordingly, the expected future number of student auto
trips made to the academic zone around 8:30 a.m. was esti-
mated and assumed equal to the expected peak student load
on the bus system. This estimate was arrived at by using
the student parking demand forecasting model. The value of
"C" used in this case was 0.27 (the percent of students ex-
pected to commute to the academic zone around 8:30 a.m.).
It was thus estimated that if a bus system (or systems) is
used, it could have a peak load of 2150 students around 8:30
a.m. Of these, about 430 students are expected to be living
in university housing facilities.

Pedestrian Commuting. Most of the pedestrian trips
made to the academic zone are generated by university housing
facilities and fraternities, sororities, and cooperative
houses located in the vicinity of the academic zone. In the
future, commuting from these kinds of residential facilities
is expected to remain predominantly pedestrian. The follow-
ing is an analysis of the existing as well as the expected

---

* To obtain accurate estimates of the expected student loads
  on a bus system at different hours would require the use of
  sophisticated data on the probable frequencies of student
  trips from the academic zone back and forth to their resi-
  dences between classes.

pedestrian-vehicle conflicts resulting from pedestrian commuting to the academic zone.

The actual frequencies and paths of pedestrian trips made from origins outside of the academic zone to destinations within it are difficult to plot; more so to forecast. However, by plotting and examining schematic pedestrian desire lines based on estimates of pedestrian trips generated by different housing facilities and hypothetically attracted to the focal point in the academic zone, the locations of heavy pedestrian movements to and from the academic zone can be identified. Figure 15 shows a schematic configuration of the existing pedestrian desire lines to and from the academic zone. The heaviest pedestrian traffic approaches the academic zone from the west and the north; especially through First, Second, and Third Streets. In the future, the same pattern is expected to remain, probably with increasing pedestrian traffic approaching the academic zone from the south (due to the expected provision of additional graduate housing facilities south of State Street).

Existing volumes of vehicular traffic around the academic zone are shown in Figure 16 (24). Northwestern Avenue and State Street are the main approaches to the academic zone. Other surrounding streets carry much less vehicular traffic. These serve to distribute traffic to the parking facilities in and around the academic zone. Short of drastic changes in the street network around the academic zone, the same

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968

FEET

N

☐ UNIVERSITY BUILDINGS

-- RAILROAD

☐ ACADEMIC ZONE

PEDESTRIAN TRIPS
4000
1,500
500 100
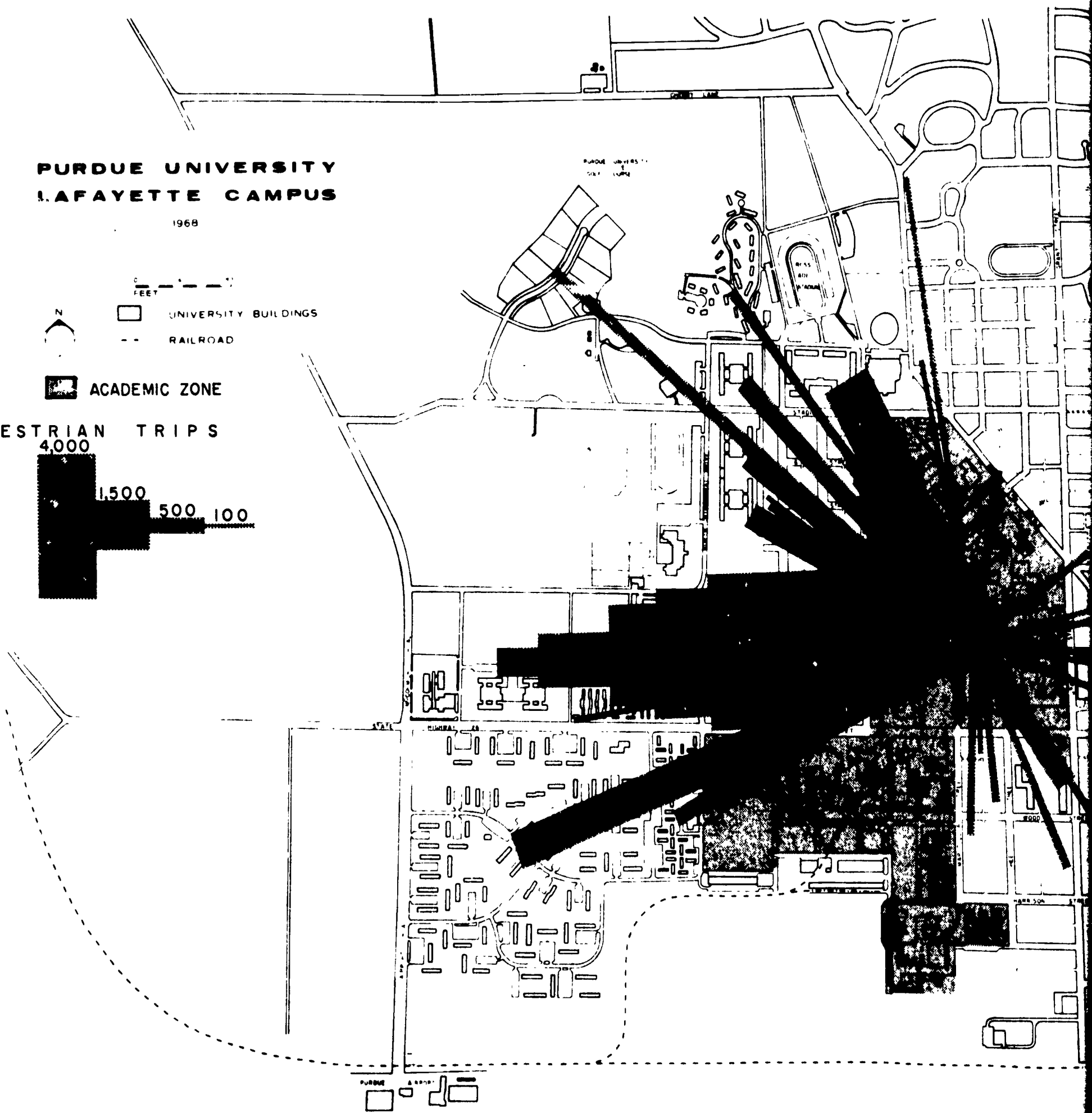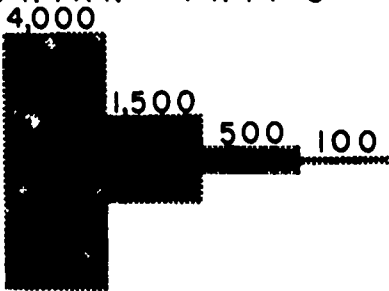
FIGURE 15 — SCHEMATIC CONFIGURATION OF PEDESTRIAN DESIRE LINES TO
THE ACADEMIC ZONE, FALL 1967
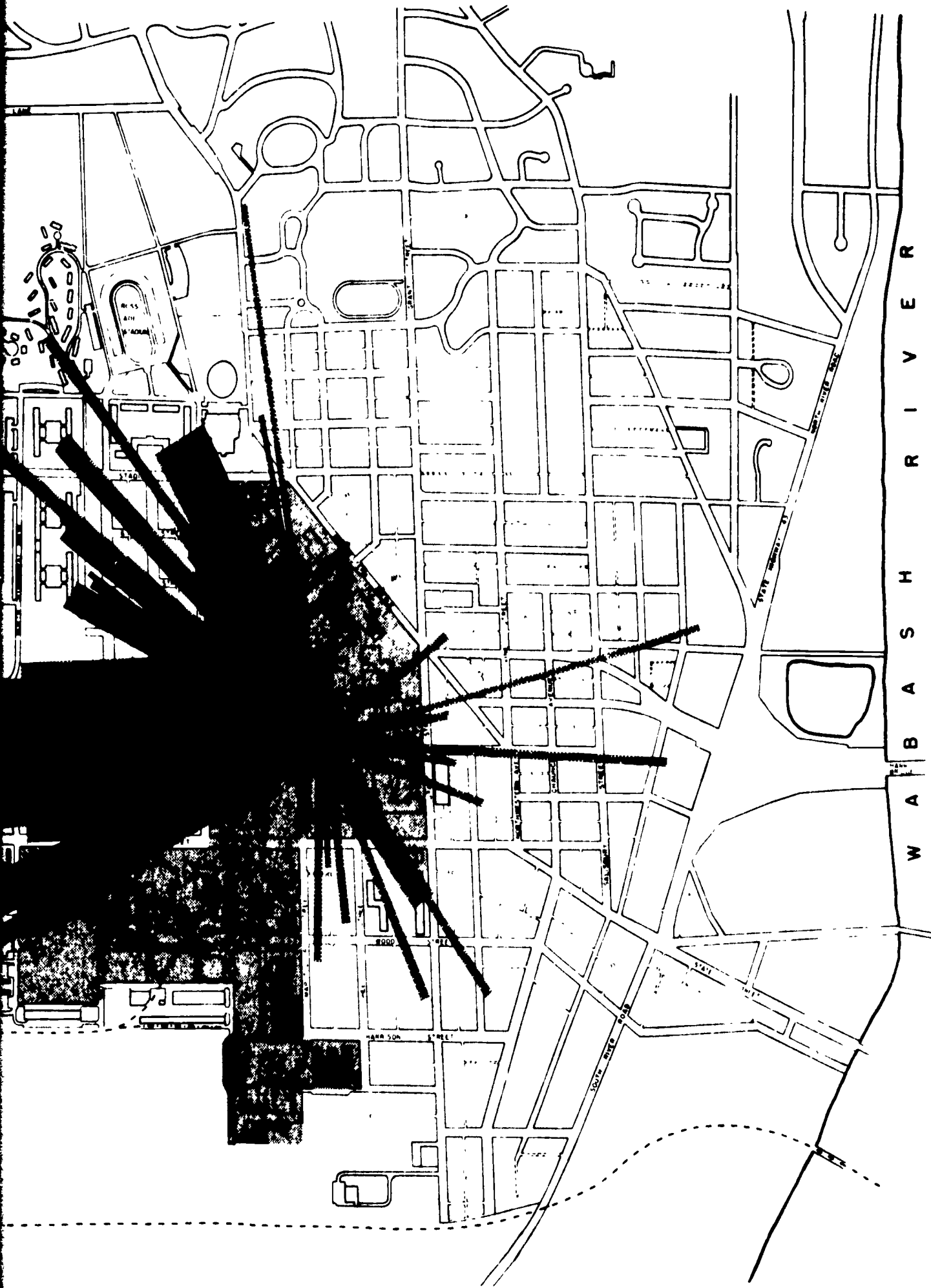
STRIAN DESIRE LINES TO AND FROM
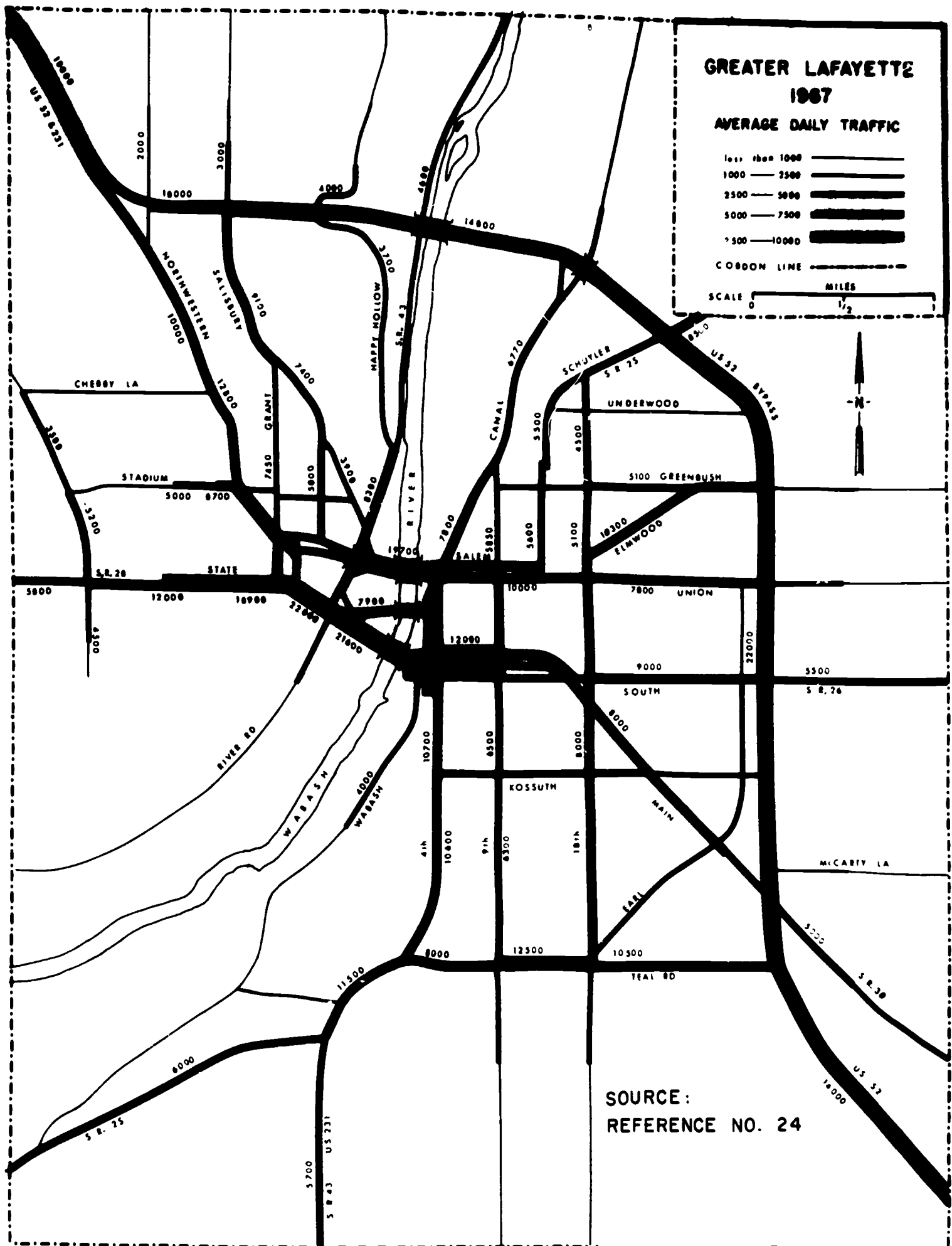
FIGURE 16 - AVERAGE DAILY TRAFFIC VOLUME MAP, 1967

traffic pattern is expected to remain unchanged in the future. Volumes of traffic, however, will obviously increase.

By examining the patterns of pedestrian traffic and vehicular traffic together, existing and expected pedestrian-vehicle conflicts can be located. Such conflicts presently occur and will tend to increase on Stadium Avenue, along University, Waldron, and Russell Streets, and most importantly on State Street. No significant conflicts seem to occur along Northwestern Avenue. Fortunately, peak vehicular traffic does not concur with peak pedestrian traffic. As such, pedestrian-vehicle conflicts around the academic zone may be subject to possible solutions.

Summary

This chapter discussed data collection, data analysis, and forecasting. The patterns of movement in the academic zone were analyzed, the efficiency of the present layout of facilities was evaluated, and the pedestrian-vehicle conflicts in the academic zone were located. Future expected conditions in the academic zone were discussed. Commuting to and from the academic zone was also examined. Data on the campus population characteristics influencing commuting were collected and analyzed. Expected future population characteristics were estimated and techniques for forecasting commuting demands were developed. Thus future parking demands and the peak student load on a possible bus system that might be used as an alternative mode of commuting to

and from the academic zone were estimated. Finally, pedestrian-vehicle conflicts around the academic zone were examined.

The results arrived at in this chapter provide the factual bases on which a number of alternative circulation and commuting plans are developed in the next chapter.

CHAPTER III. ALTERNATIVE PLANS FOR CIRCULATION AND COMMUTING

The existing conditions relative to circulation in the academic zone and commuting to and from it were analyzed. Deficiencies were noted and future demands were estimated. A number of alternative plans were developed to overcome the existing deficiencies and meet the future demands. These were then evaluated in terms of their capabilities to fulfill objectives and in terms of their annual costs. The following are the objectives set for these alternatives and the criteria by which they were evaluated.

Objectives and Criteria

Objectives

In his general discussion of campus circulation systems, Dober proposed a number of objectives (5). On the basis of these, specific objectives were formulated to suit the purpose and scope of this study. The alternative plans for circulation and commuting were developed with the following objectives:

1. To create, whenever practicable, traffic-free pedestrian precincts in the academic zone.

2. To separate the channels of movement of incompatible modes of transportation.

3. To provide logical connections in traffic flow.

4. To meet, as adequately as feasible, the demand for
    parking.

5. To choose, within the limitations of land avail-
    ability and uses, convenient locations for parking.

6. To provide for the appropriate servicing of build-
    ings.

7. To create an aesthetically pleasing environment on
    the campus.

Criteria

Circulation and commuting plans were evaluated in terms
of the following criteria: (1) continuity of the circula-
tion system and clarity of destinations, (2) safety for both
pedestrians and drivers, (3) convenience in driving and
walking, (4) enjoyment of an aesthetically pleasing environ-
ment especially in walking, and (5) cost.

Alternative Circulation Plans (In the Academic Zone)

Analysis of pedestrian circulation in the academic zone
indicated the presence of pedestrian-vehicle conflicts in a
number of locations. Three alternative plans were developed
to minimize these conflicts. In the first (alternative
I/1) the conflicts are almost entirely eliminated. In the
second and third (alternatives I/2 and I/3) the conflicts are
partially eliminated with varying degrees. In all three
alternatives, most parking facilities presently available on

the periphery of the academic zone are kept in use. Build-
ings are serviced through these parking facilities. When-
ever through vehicular traffic is eliminated by vacating or
dead-ending internal streets, provision can be made for emer-
gency vehicles to use pedestrian walkways for access. In
all three alternatives, the railroad line is removed on the
assumption that the existing power plant on the north campus
will be relocated.

Alternative I/1

In this alternative, through traffic was completely
eliminated from the academic zone. Pedestrian circulation
is given prime importance while vehicular traffic is strictly
kept to a minimum. ·Figure 17 shows alternative plan I/1.
On the north campus, vehicular traffic was eliminated on
Oval Drive, on Memorial Mall, south of the Chemistry building,
on Central Drive, around the Hall of Music, on Purdue Mall,
and on Stadium Mall. This was done to minimize the inter-
ference, in these locations, between vehicular traffic and
the heavy concentrations of pedestrians. On the south campus,
pedestrian-vehicle conflicts are as yet relatively less
noticeable. However, a few changes were made in the existing
vehicle circulation system to minimize increases in such
conflicts in the future. Thus vehicular traffic was eliminated
south of the Life Science Small Animal building, east of the
Agricultural Engineering building, west of the Horticulture
building, and west of the Agricultural Hall.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968

N

FEET

☐ UNIVERSITY BUILDINGS

-- RAILROAD

■ VEHICULAR NETWORK

■ PEDESTRIAN PATHS

STREET ELEVATED TO ALLOW PEDESTRIAN CIRCULATION UNDERNEATH

ROSS ADE STADIUM

GRANT STREET

SHERRY LANE

STADIUM

6TH

5TH

4TH

3RD

2ND

STREET

WALDRON

RUSSELL

STREET

HIGHWAY 26

McCORMICK ROAD

STATE

71

STREET ELEVATED TO ALLOW PEDESTRIAN CIRCULATION UNDERNEATH
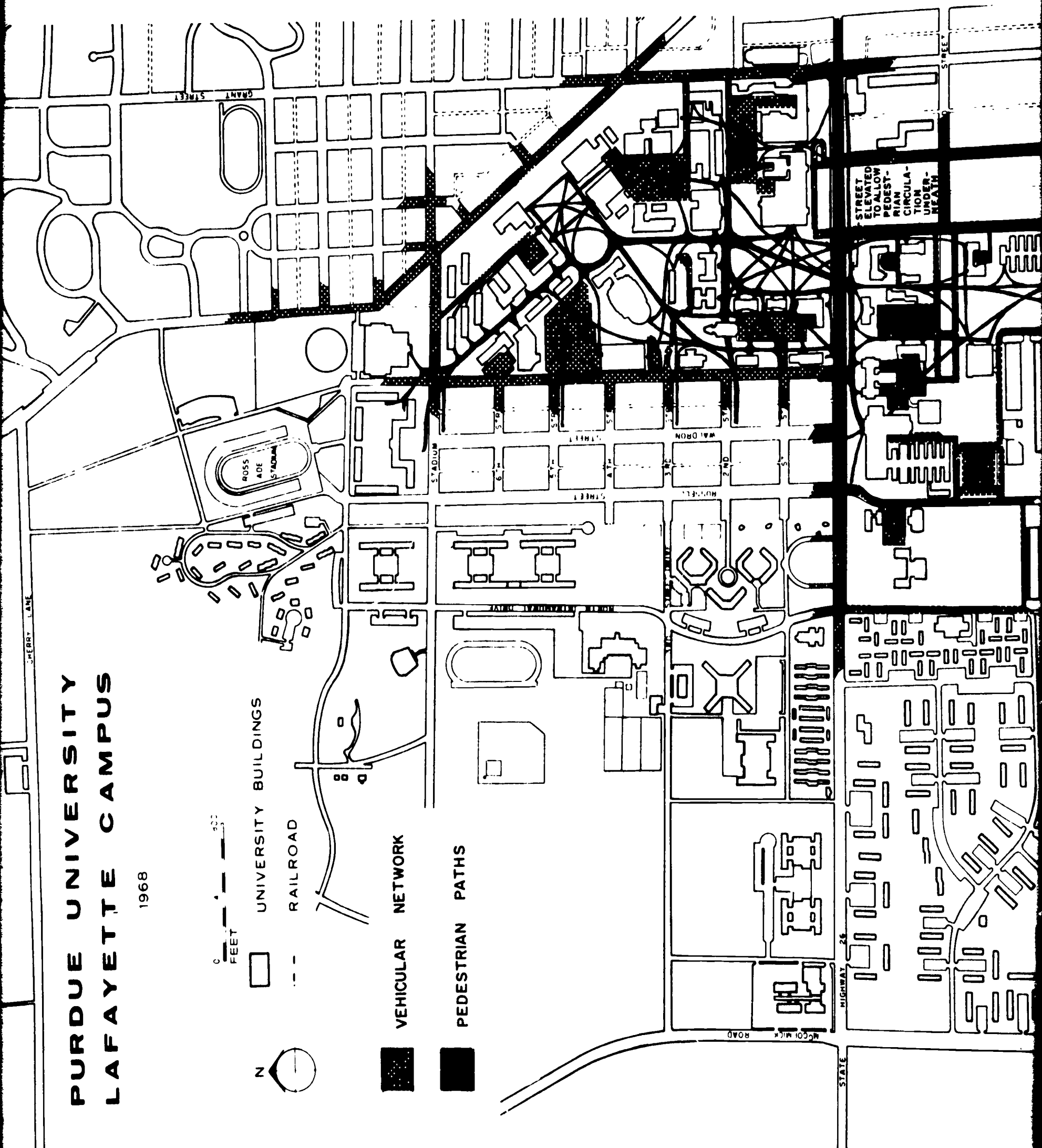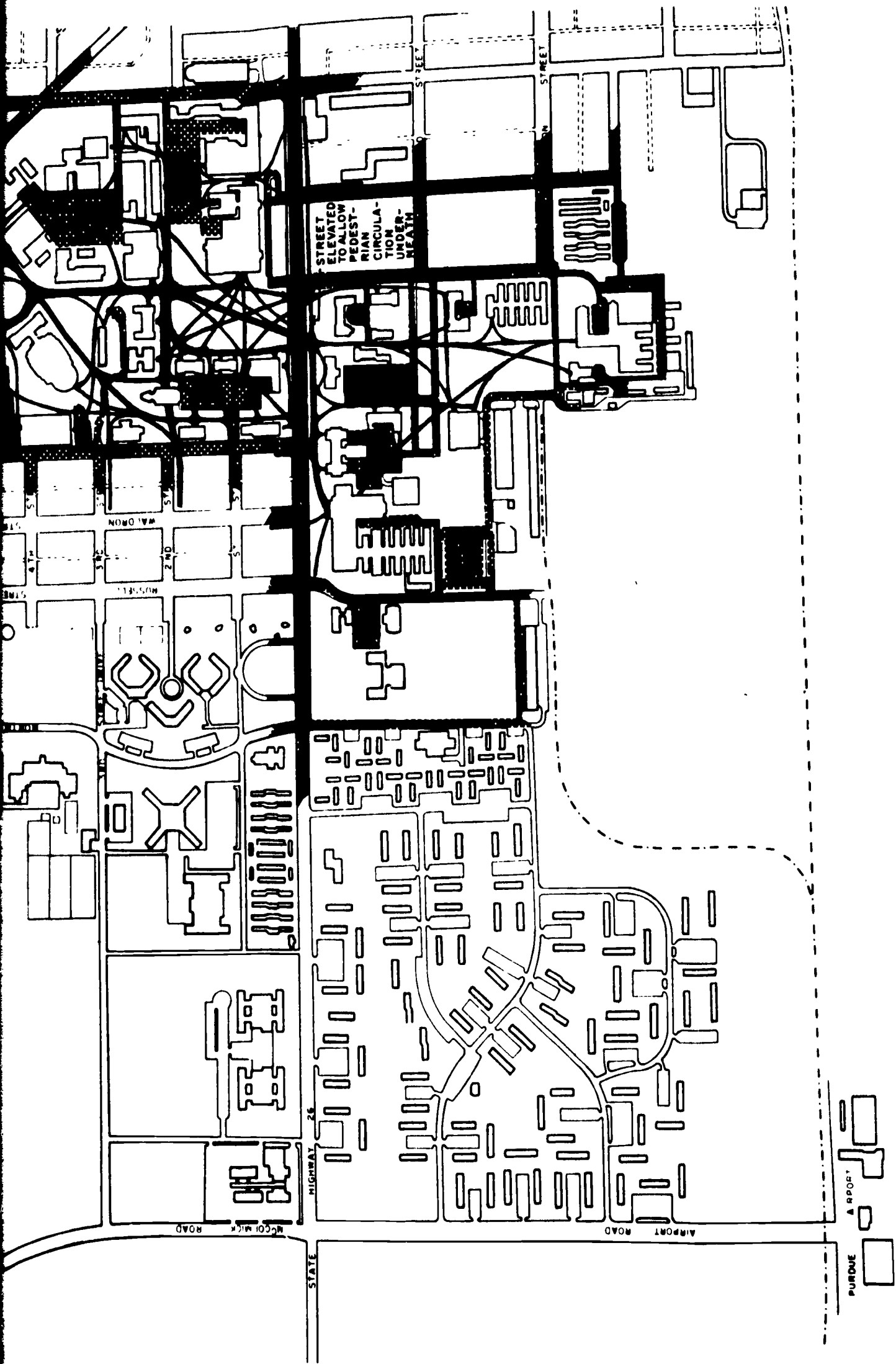
FIGURE 17 — ALTERNATIVE PLAN I/I —(CIRCULATION IN THE ACADEMIC ZONE)

It was recognized that the penetration of State Street into the campus creates one of the major pedestrian-vehicle conflicts in the academic zone, a conflict that is likely to increase considerably in the future. In this alternative, the solution proposed to overcome this conflict is based on the concept of complete integration of the south and north campuses. This is achieved by slightly raising the level of the stretch of State Street west of Memorial Mall and east of the Home Economics Administration building, and by slightly lowering the level of the open spaces north and south of this raised portion of State Street just enough to allow pedestrian movement underneath State Street (Figure 18). Continuity can thus be achieved in the flow of open spaces and in pedestrian circulation between the north and south campuses. The solution, however, requires considerable change in the design of the intersection of State Street with Marsteller Street.

Alternative I/2

Figure 19 shows alternative plan I/2. In this alternative, through traffic is also eliminated on the north campus. Peripheral parking facilities which do not conflict with major pedestrian paths are kept in use. The parking on Purdue Mall, northeast of the Music Hall, and north of the Memorial Center and Memorial Union are left unchanged. Major pedestrian-vehicle conflicts are minimized by converting Stadium Mall, Oval Drive, and Memorial Mall into pedestrian walkways. On the south
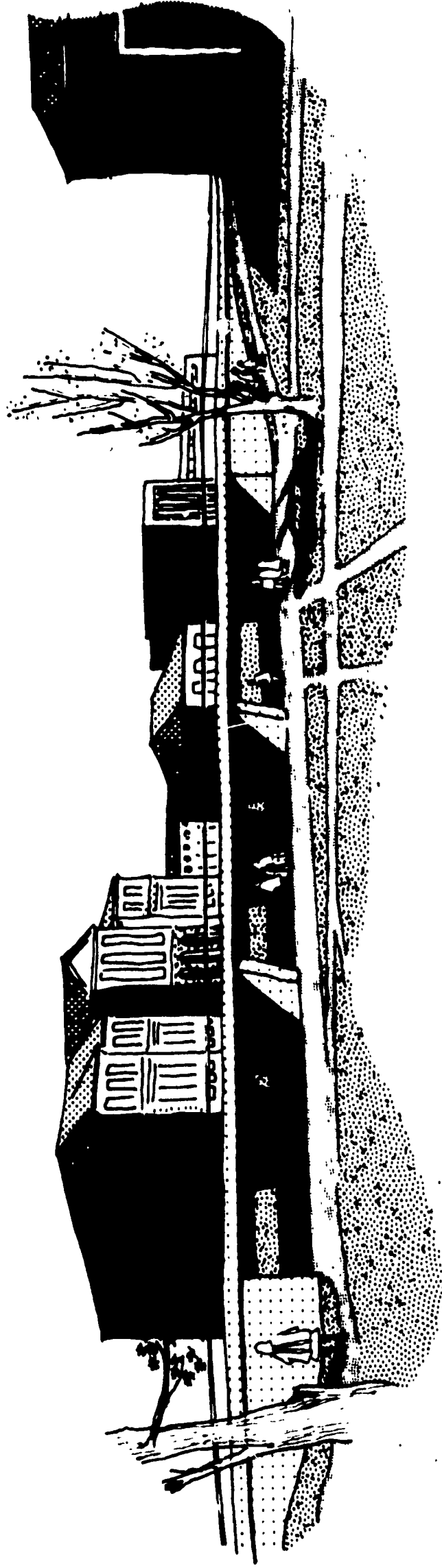
FIGURE 18 — PROPOSED INTEGRATION OF THE NORTH AND SOUTH CAMPUSES —
A GENERAL VIEW

PURDUE UNIVERSITY LAFAYETTE CAMPUS

1968

UNIVERSITY BUILDINGS

RAILROAD

VEHICULAR NETWORK

PEDESTRIAN PATHS

N

PEDES-
TRIAN
UNDER-
PATH
UNDER
ELEVAT-
ED ST.
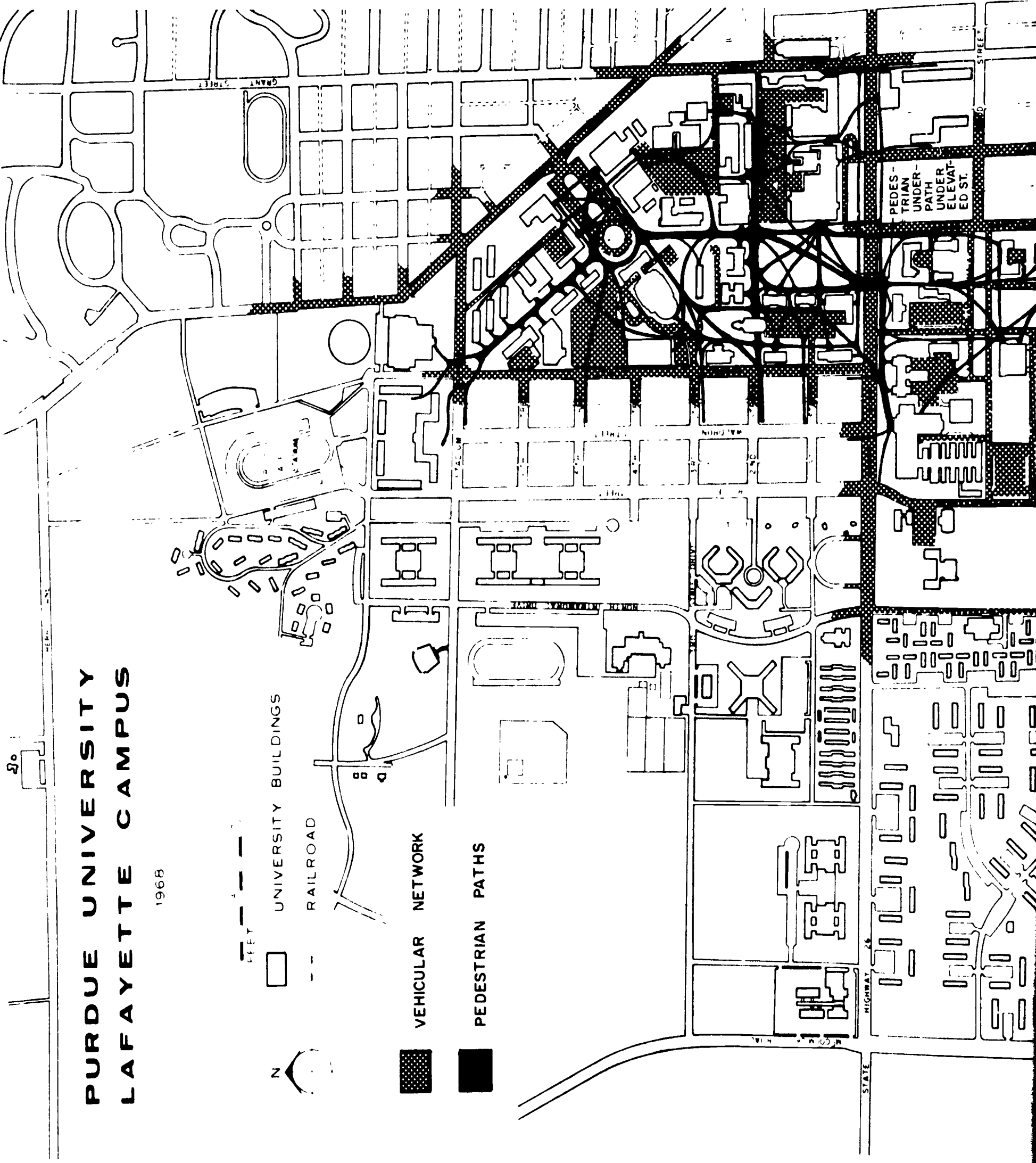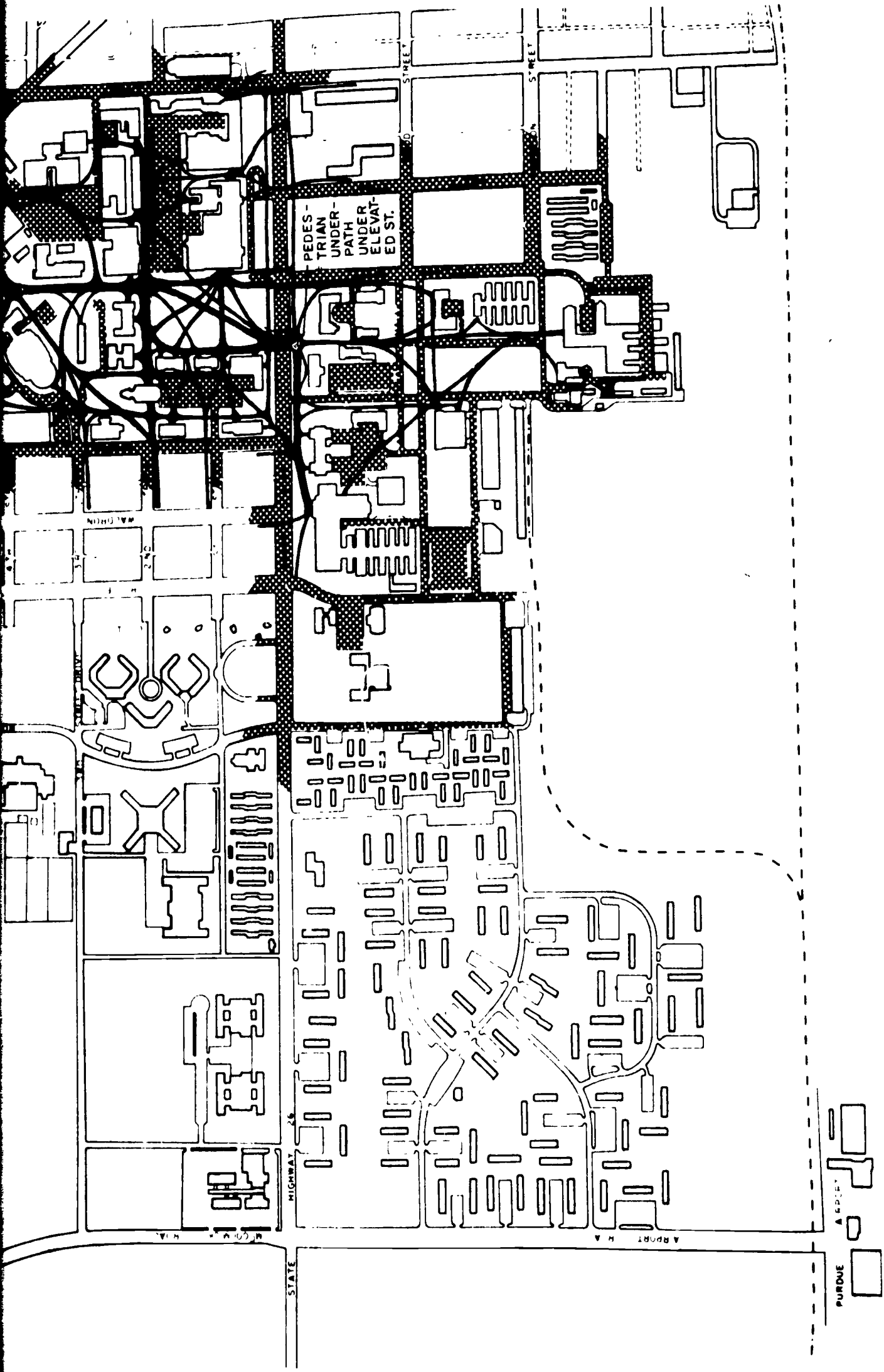
FIGURE 19 — ALTERNATIVE PLAN I/2 — (CIRCULATION IN THE ACADEMIC ZONE)

campus, no changes are made in the circulation system. If the existing pattern of dead-end streets is maintained in the future, no major pedestrian-vehicle conflicts are likely to arise in the south campus.

To overcome the pedestrian-vehicle conflict on State Street, an open pedestrian underpass is proposed (Figure 20). In choosing the location of the underpass, the points at which the greatest concentrations of students cross State Street between classes were repeatedly observed. Accordingly, it was felt that the underpass would be most intensely used if located east of the Home Economics Administration building. Also, by slightly raising the level of State Street at this location and by slightly lowering the level of the proposed underpass (just enough to allow pedestrian movement), no major changes will be required in the adjacent intersections. The solution provides only partial integration of the north and south campuses but satisfactorily eliminates the major pedestrian-vehicle conflict on State Street.

Alternative I/3

Figure 21 shows alternative plan I/3. Unlike alternatives I/1 and I/2, this alternative seeks only to minimize (and not completely eliminate) through traffic on the north campus. Parts of Oval Drive, Central Drive, and Memorial Mall are closed to vehicular traffic. Stadium Mall is used for one-way traffic (going south) leading to the parking
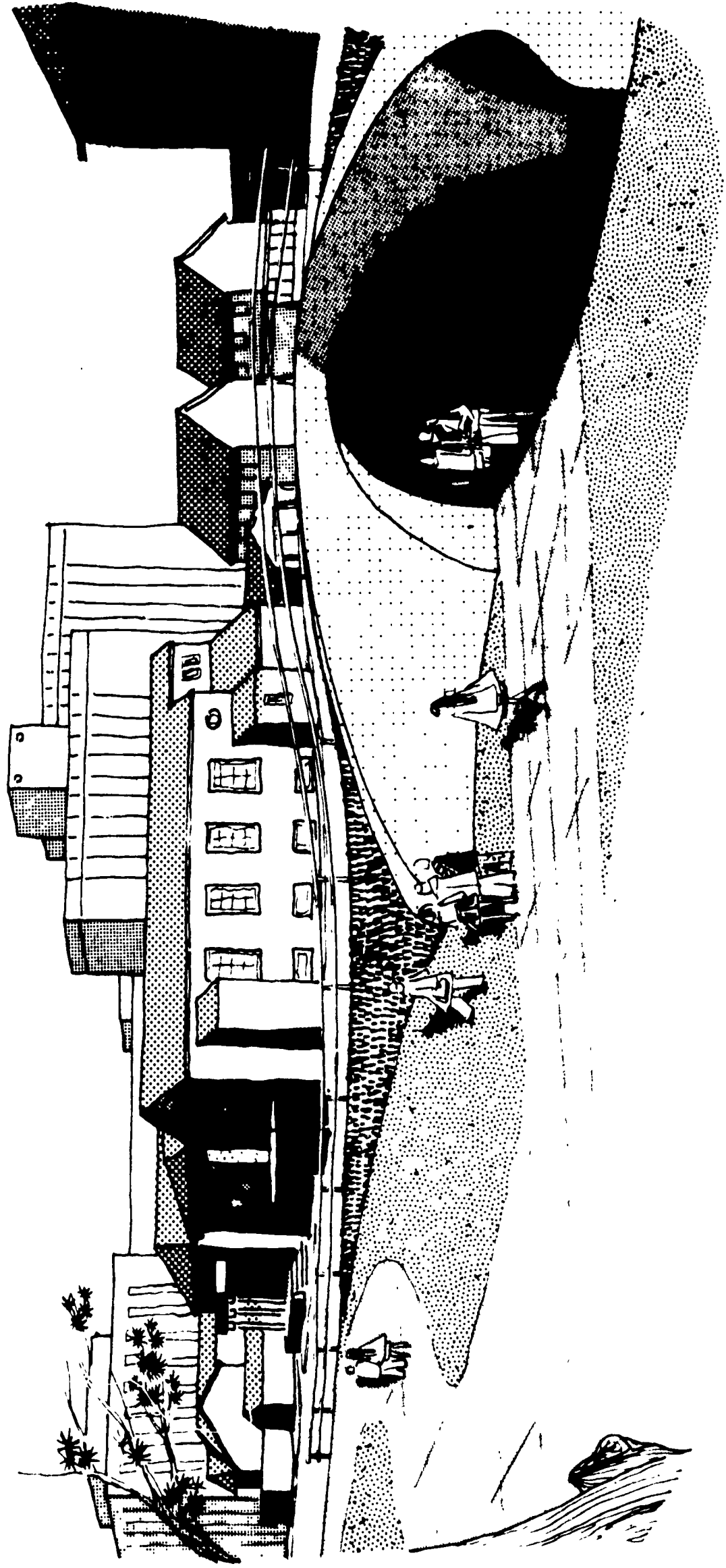
FIGURE 20 – PROPOSED PEDESTRIAN UNDERPASS – A GENERAL VIEW
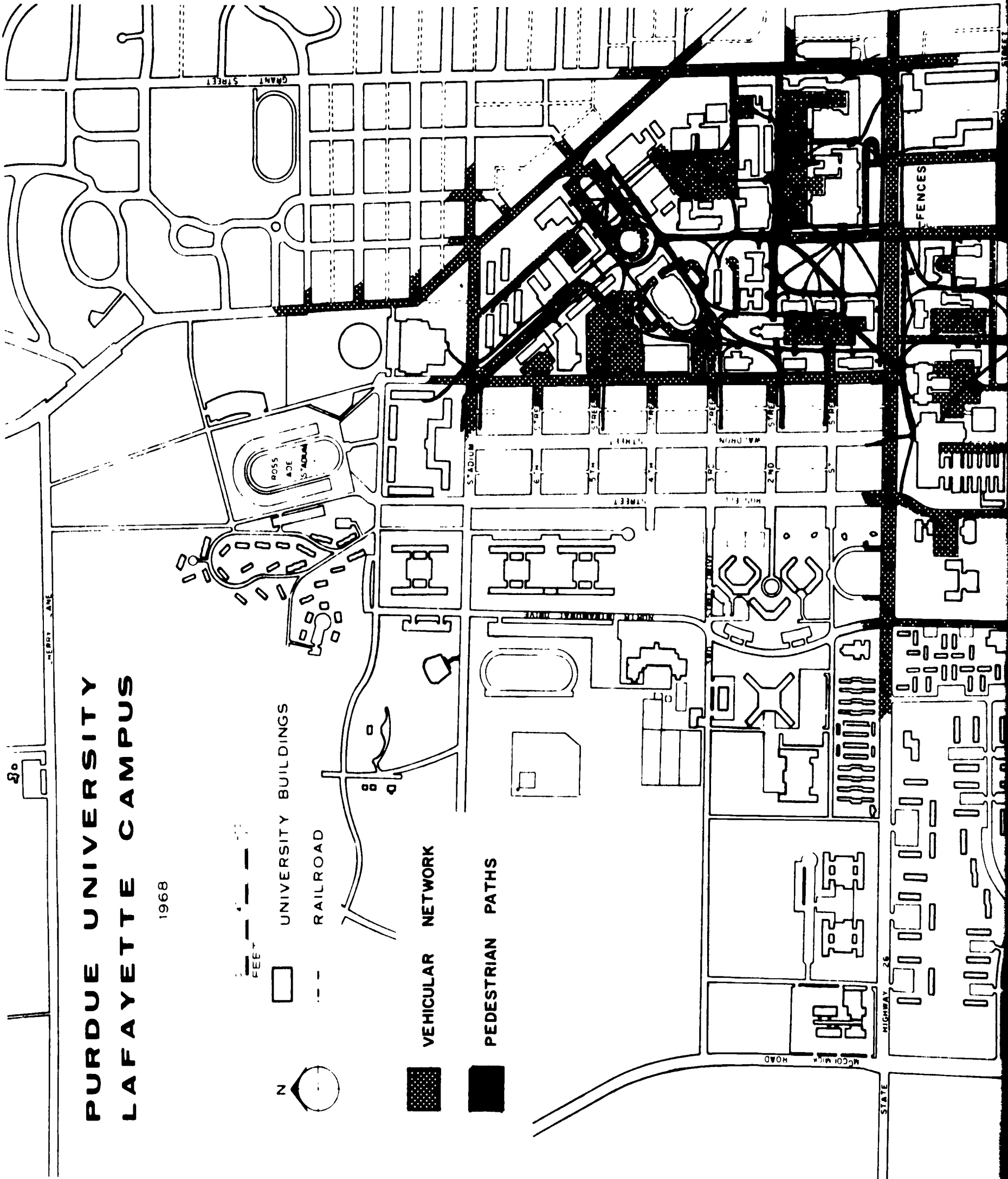
PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968

☐ UNIVERSITY BUILDINGS

– – – RAILROAD

■ VEHICULAR NETWORK

■ PEDESTRIAN PATHS

FEET

N

GRANT STREET

STADIUM

6TH STREET

5TH STREET

4TH STREET

3RD STREET

2ND STREET

1ST STREET

WALNUT

STREET

STREET

ROSS ADE STADIUM

MERCY LANE

30

FENCES

STATE HIGHWAY 26

McCORMICK ROAD

NORTH UNIVERSITY DRIVE
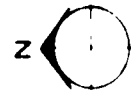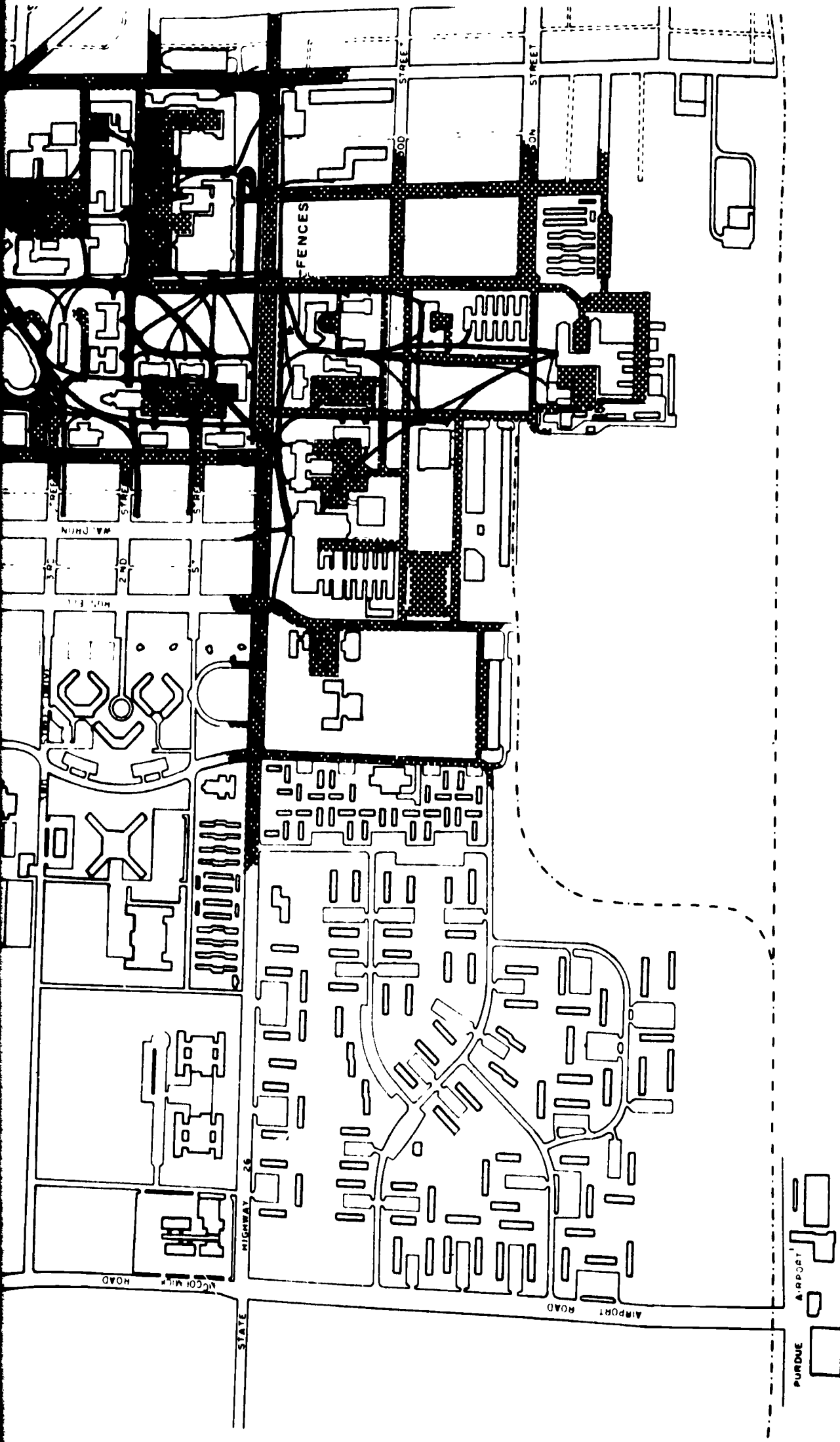
FIGURE 21 — ALTERNATIVE PLAN 1/3 — (CIRCULATION IN THE ACADEMIC ZONE)

lot abbuting University Street (Figure 21). As in alternative I/2, no changes are made on the south campus. The pedestrian-vehicle conflict on State Street is reduced by using a more complete system of decorative fences along the street to limit the points of crossing and by providing traffic controls at these points.

Evaluation of Alternatives

The following is a subjective evaluation of the three alternative circulation plans in terms of the criteria outlined earlier in this section. The evaluation is subjective in the sense that it does not attempt to quantify the attributes and characteristics of each alternative, but instead, discusses them qualitatively.

In both alternatives I/1 and I/2, continuity is fully achieved in both vehicular and pedestrian circulation. In alternative I/3, pedestrian circulation is interrupted, at a number of points, by vehicular traffic. In terms of safety, both alternatives I/1 and I/2 succeed in eliminating the major hazards caused by pedestrian-vehicle conflicts, but in alternative I/3 the conflict on State Street is not fully overcome.

In all three alternatives, driver convenience is reduced (to varying degrees) by eliminating access to parking facilities from internal streets (in the academic zone) and by limiting this access to single points on the surrounding streets. Not only will this mean longer trips in some cases

(by automobile and on foot), but it might also create some mild traffic congestion on the surrounding streets during peak hours. Access for service and emergency vehicles can be adequately provided in all three alternatives.

Aesthetically, the potential exists in all three alternatives for creating pleasing visual relationships in the academic zone. In alternatives I/1 and I/2, the grade separation of pedestrians and vehicular traffic on State Street creates wide possibilities of landscaping and open space organization.

For this evaluation, cost was found to result primarily from two measures: (1) the number of parking spaces in the academic zone that would be lost due to the proposed changes, and (2) the extensiveness of the proposed changes. Alternative I/1 has the greatest reduction in the number of parking spaces (about 766 spaces). Of the three alternatives, it also proposes the most extensive changes in the existing conditions. As such, it will undoubtedly prove to be the most expensive to implement. Conversely, alternative I/3 will result in reducing the number of the existing parking spaces in the academic zone by only about 142 spaces and will require the least extensive changes. Alternative I/2 lies between the two extremes; it involves the reduction of about 302 parking spaces and requires moderate changes in the existing conditions.

On the basis of this evaluation, it seems justified to conclude that, of the three proposed alternatives,

alternativ I/2 would be most acceptable. It will minimize
the major pedestrian-vehicle conflicts in the academic zone;
it will reasonably link the north and south campuses; and
it would require only moderate costs to effect necessary
changes in the existing conditions. Alternative I/2 is con-
sequently used as the basis for developing alternative com-
muting plans.

Alternative Commuting Plans (To and From the Academic Zone)

Commuting to and from the academic zone and circulation
in the academic zone, although examined separately, are
interrelated. Both are phases of an integral campus trans-
portation system. The alternative commuting plans proposed
in this section, therefore, are developed in connection with
the selected circulation plan (alternative I/2). However, few
changes are expected to arise (especially in future parking
demands) if some other circulation plan (in the academic zone)
is selected.

Three alternative commuting plans are proposed. In the
first (alternative II/1), it is assumed that all expected
auto trips to the academic zone will terminate in or around
it. Therefore, all future parking demand (for students,
staff, and visitors) is provided in and around the academic
zone. The second (alternative II/2) uses a combination of
parking facilities around the academic zone and a bus system
to move students from university housing facilities to the
academic zone. The third and last (alternative II/3) is based

on the concept of providing parking facilities in relatively
remote locations and moving commuters from these parking lots
to the academic zone by mass transportation. Two types of
mass transportation systems are compared. In sub-
alternative II/3-A, a street bus system is proposed and in
sub-alternative II/3-B, the possibility of using a skybus
system operating on an elevated roadway is discussed.

In all three alternatives, no additional parking is
provided on the north campus. Of the existing on-street
free parking around the academic zone, 1000 spaces are
assumed to be available for commuter parking in the future.
In addition to these and the existing parking spaces in the
academic zone, it was estimated that, to meet the future
commuting demands of students, staff, and visitors, about
4330 additional spaces will either have to be provided or
some other mode of commuting to the academic zone will have
to be developed.* In developing the alternative commuting
plans, due consideration was given to pedestrian commuting.
Locations of future parking facilities were chosen so as to
minimize pedestrian-vehicle conflicts and to allow for ap-
propriate traffic controls at major pedestrian crossing
points.

---

* For the details of this estimate, see Appendix B - Section
  2.

Alternative II/1

In this alternative, future commuting demands are met by providing parking facilities around the academic zone. Figure 22 shows alternative plan II/1. A number of possible kinds and locations of parking facilities were examined. A comparison was made between the annual costs of different kinds of parking facilities such as underground garages, multi-story above ground garages, and surface parking. The costs of providing parking facilities on university owned land and on non-university owned land were also compared. Appendix B - section 1 shows a detailed comparison of the annual costs of four kinds of parking facilities. Underground parking in the academic zone was discarded because of its relatively high costs. Surface parking on close-by locations around the academic zone in most cases was rejected because of the limited availability of usable land in general and university owned land in specific. The provision of parking in multi-story above ground garages around the academic zone was found to be the least expensive and the most appropriate from a land use and pedestrian circulation point of view. On the fringes of the south campus, however, surface parking is most economical because of university owned land.

In deciding upon the locations of future parking facilities (Figure 22), a number of factors were taken into consideration:

PURDUE UNIVERSITY LAFAYETTE CAMPUS

1968

FEET

☐ UNIVERSITY BUILDINGS

-- RAILROAD

▨ ACADEMIC ZONE

▨ FOUR-STORY GARAGE

■ SURFACE LOT

400 P.S.

400 P.S.

400 P.S.

850 P.S.
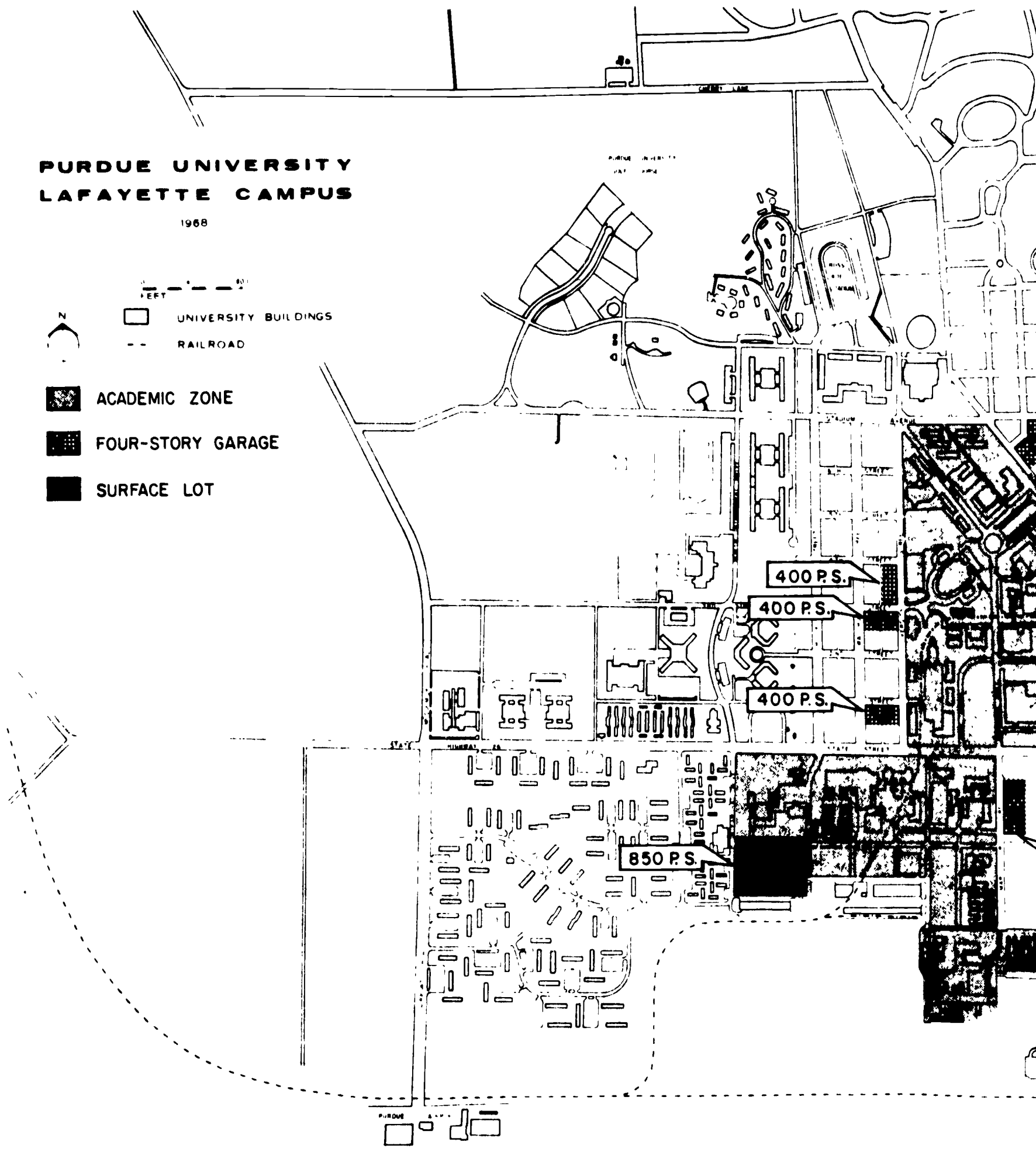
FIGURE 22 — ALTERNATIVE PLAN II/I — (COMMUTING TO AND FROM T
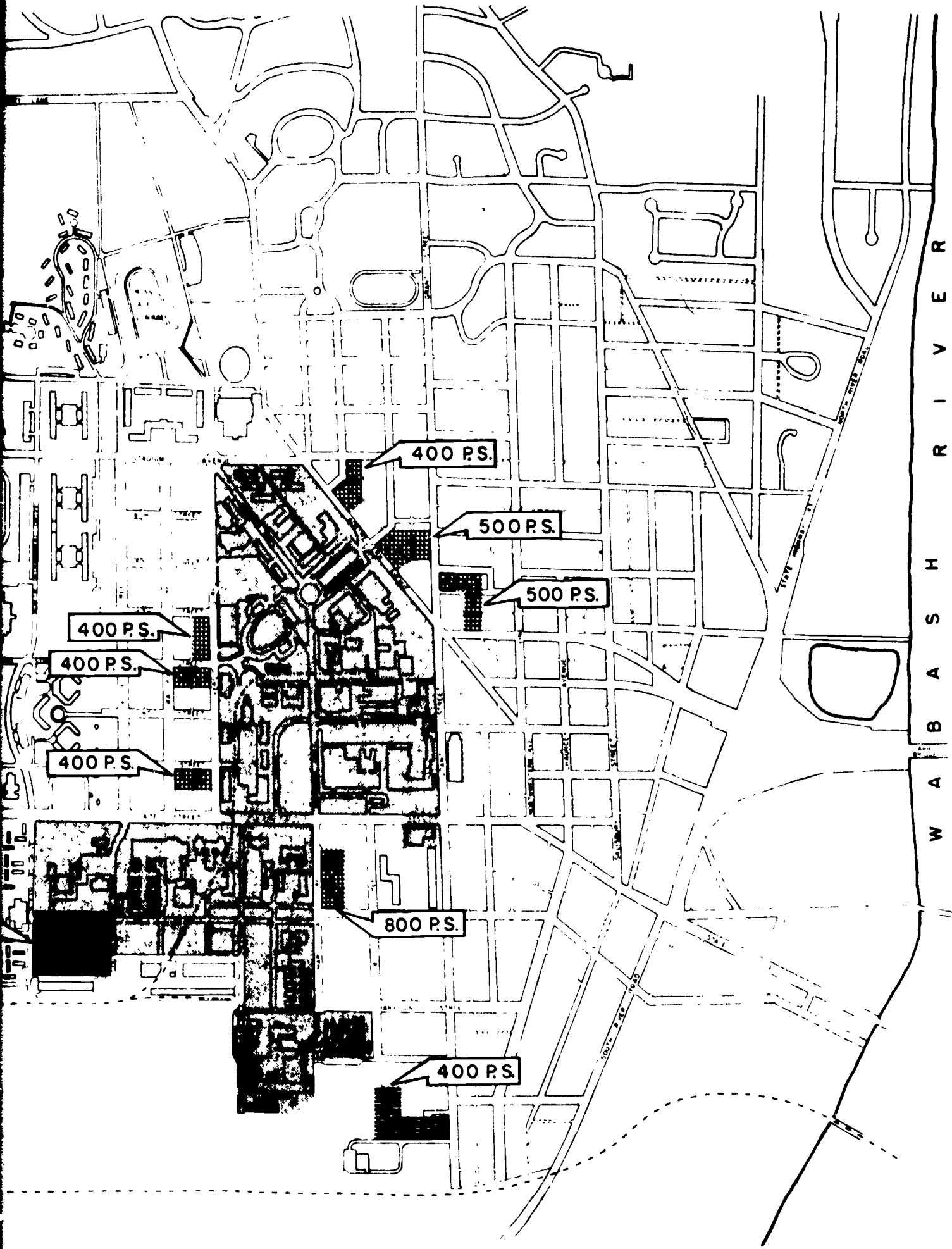
(MUTING TO AND FROM THE ACADEMIC ZONE)

1. Parking facilities should be located, whenever
   possible, near the major traffic approaches to the
   academic zone. This enhances driver convenience
   and minimizes unnecessary vehicular movement around
   the academic zone. Thus, locations on Northwestern
   Avenue, University Street, Grant Street, Fowler
   Street and Wood Street were chosen for multi-story
   garages.

2. Location of parking facilities should minimize con-
   flict at points of major pedestrian crossings. The
   entrances and exits of such facilities should be
   carefully designed to minimize pedestrian-vehicle
   conflicts. Thus, parking facilities on University
   Street were not located adjacent to Second Street
   because of the expected heavy pedestrian use of
   this street. However, if a pedestrian ramp along
   Second Street with a separated crossing of Univers-
   ity Street were to be integrally constructed as a
   part of a garage on the south side of Second Street
   between Waldron and University Streets, separation
   of pedestrians and vehicles would be better ac-
   complished.

3. In choosing parking locations, proximity to intensely
   used facilities in the academic zone secures pedest-
   rian convenience. Multi-story garages were, there-
   fore, located as close as possible to the main in-
   structional facilities in the academic zone.

Along these lines, alterntative II/1 provides about
1250 parking spaces in surface lots on the south campus and
about 3400 parking spaces in multi-story garages around the
academic zone (Figure 22).   The annual cost involved in
implementing this alternative is estimated in Appendix B -
section 2.

Alternative II/2

This alternative is developed on the basis of providing
a combination of parking facilities around the academic zone
and a bus system.   Two possible systems were considered:
(1) a bus system connecting the academic zone to the princi-
pal apartment complexes in West Lafayette and to the uni-
versity housing facilities, and (2) a bus system connecting
the academic zone to the university housing facilities only.
The first was discarded because of the excessively long trip
involved and the long time required to make such a trip by
bus.   The second was used as a basis for developing this
alternative.

Since this proposed bus system is operated only between
the academic zone and university housing facilities, it likely
will substitute for only a fraction of the need for auto
trips.   The system is thus combined with parking facilities
around the academic zone to meet the future commuting demand.
Figure 23 shows alternative plan II/2.   The figure gives
the proposed bus route as well as the types and locations
of the parking facilities around the academic zone.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968

```
0                    '
FEET
```

☐   UNIVERSITY BUILDINGS

– –   RAILROAD

▨   ACADEMIC ZONE

▨   FOUR-STORY GARAGE

▰   SURFACE LOT

▨   RESIDENTIAL FACILITIES SERVED
    BY THE BUS SYSTEM

●   BUS STATION

▼   BUS ROUTE

400 P.S.

400 P.S.

400 P.S.

850 P.S.

600 P.S.

400
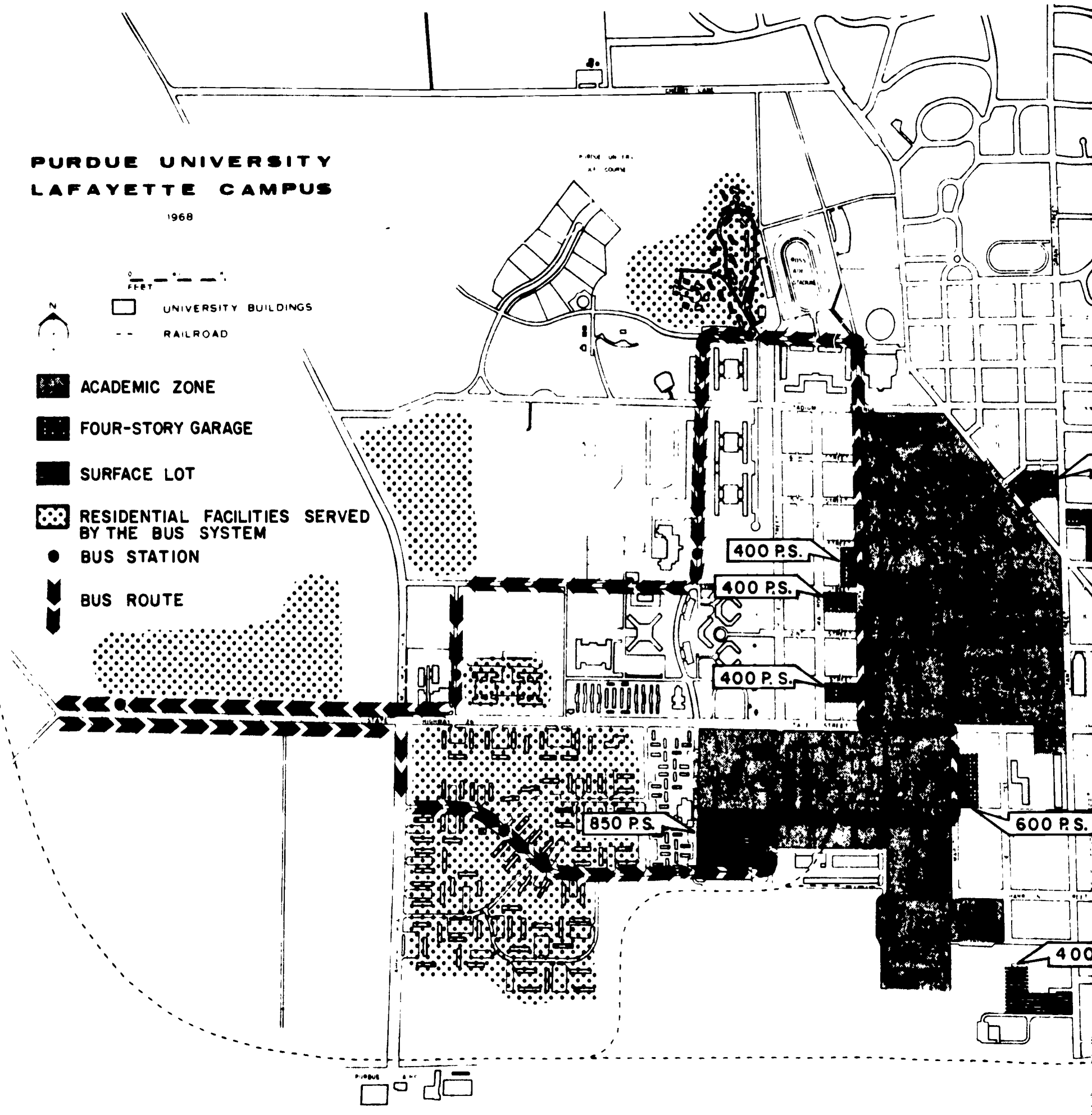
FIGURE 23 — ALTERNATIVE PLAN II/2 — (COMMUTING TO AND FROM THE

500 P.S.

500 P.S.

00 P.S.

0 P.S.

0 P.S.

600 P.S.

400 P.S.

W A B A S H   R I V E R
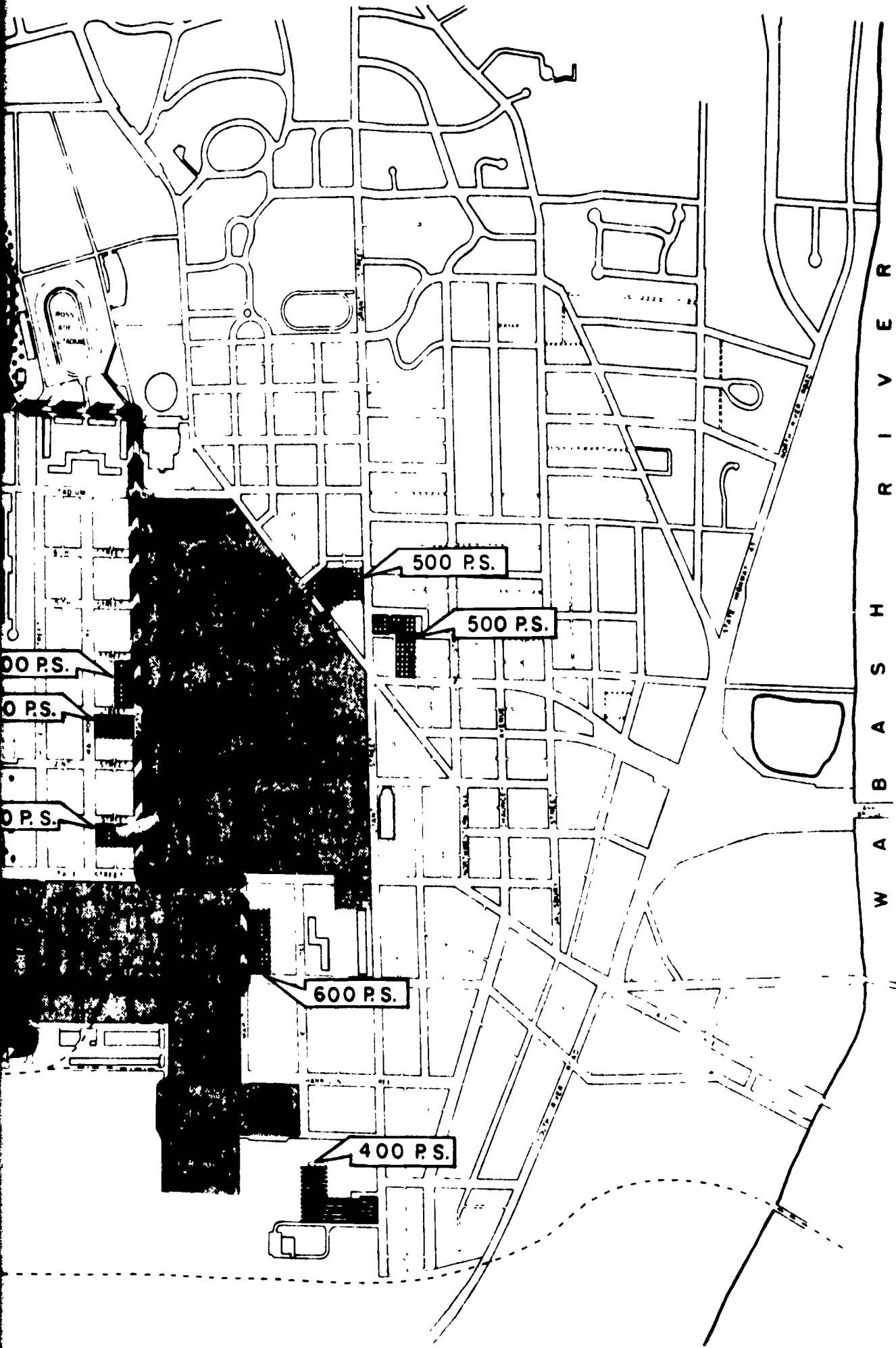
NG TO AND FROM THE ACADEMIC ZONE)

According to this bus route, the round trip would be about five miles long. The types and locations of the parking facilities provided around the academic zone are not much different from those proposed in alternative II/1. Their capacities, however, are reduced by about 600 spaces assuming that all peak-hour non-pedestrian commuters living in university housing facilities will use the proposed bus system to the academic zone instead of their private automobiles. The peak load on the bus system is estimated as equal to the number of student auto trips made by students living in university housing facilities to the academic zone around 8:30 a.m.* This peak load was found to be about 430 passengers and is expected to occur shortly before 8:30 a.m.

The requirements of the bus system were estimated on the basis of the following operational criteria:

1. The system should be able to move a peak load of about 430 passengers from university housing facilities to the academic zone in not more than twenty minutes.

2. A minimum headway of about three minutes and a maximum of about ten minutes were allowed.

3. The system is used from 7:00 a.m. till 6:00 p.m. on average weekdays and from 7:00 a.m. to 12:00 oon on Saturdays and only on days when classes are in session.

---

* Estimation of the peak load on the bus system is discussed in detail in Chapter II.

4. The average speed of the bus on the round trip is about eight miles per hour including stops and time allowed between trips (determined by field tests over the proposed route with reasonable loading, unloading, and terminal stops).

5. The peak occupancy of the bus is about seventy passengers (25).

On the basis of these criteria and the estimated peak load, nine bus units would be needed. The detailed estimates of the requirements of the system and the annual cost of implementing alternative II/2 appear in Appendix B - section 3.

Alternative II/3

Unlike alternatives II/1 and II/2, in this alternative, no additional parking facilities are provided around the academic zone. Instead, parking is provided in relatively remote locations and bus systems are operated to move parkers from these remote parking facilities to the academic zone. Two types of bus systems were compared: (1) a regular street bus system, and (2) a new transportation device known as the skybus. Sub-alternative II/3-A proposes two remote parking facilities both connected to the academic zone by means of street bus systems. Sub-alternative II/3-B proposes the same parking facilities. Of these, one is connected to the academic zone by a street bus system while the other is connected by a skybus system. The two

sub-alternatives (A and B) are developed primarily to compare the two types of bus systems.

In choosing the locations of remote parking facilities, several sites were considered: (1) the Ross Ade Stadium parking lot, (2) the gravel pit south of the academic zone, (3) the intramural field west of the academic zone, and (4) the open space at the corner of Airport Road and State Street west of the married students courts. The gravel pit was discarded quickly because of its poor access and since its use would require a large amount of fill. Also to preserve the continuity of open spaces north of the single student housing facilities on State Street, the intramural field was not chosen for use as a parking facility. Thus the Ross Ade Stadium and the Airport Road locations were chosen. These locations have two advantages: (1) they abut the two main traffic approaches to the academic zone; namely, Northwestern Avenue and State Street, and (2) their proximity to university housing facilities (especially married students' housing) will probably encourage residents of these facilities to commute by the connecting buses and thus reduce the student demand on parking around the academic zone (and in the remote parking facilities). In deciding on which kind of parking facilities to provide at these locations the assumption was made that since these sites are presently owned by the university, their use would require no land cost. Under this assumption, surface parking was found to

be the least expensive and was thus used.

It was earlier estimated that, in the future, 4330 park-
ing spaces will have to be provided to meet the demand for
commuting to the academic zone. If all non-pedestrian com-
muters living in university housing facilities use the bus
systems connecting the remote parking facilities to the
academic zone, this estimate is expected to be reduced to
3730 parking spaces. These were distributed between the
two remote parking facilities in such a way that both of
the bus systems connecting these facilities to the academic
zone would carry an equal peak student load. Thus 2100
parking spaces were provided in the Ross Ade Stadium parking
facility and 1630 in the Airport Road facility.

The expected peak student load on both bus systems was
earlier estimated to be about 2150 students* (around 8:30
a.m.). In this alternative, each system carries a peak
student load of about 1075 students. Having chosen the lo-
cations of the remote parking facilities, determined the
capacity of each, and established the peak load on the bus
systems connecting them to the academic zone, the two types
of bus systems were compared.

Sub-Alternative II/3-A. In this sub-alternative, two
street bus systems were provided between the remote parking
facilities and the academic zone. Figure 24 shows the

---

* Estimation of the peak load on the bus systems is discussed
  in detail in Chapter II.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968

FEET

UNIVERSITY BUILDINGS
-- RAILROAD

ACADEMIC ZONE

REMOTE SURFACE LOT

BUS STATION

BUS ROUTE

2100 P.S.

1630 P.S.

FIGURE 24 — SUB-ALTERNATIVE II/3-A — (COMMUTING TO AND FROM THE ACA

OMMUTING TO AND FROM THE ACADEMIC ZONE)

locations of the parking facilities and the proposed bus routes. In both bus systems, the round trip length is about 3.2 miles. The requirments of each of these systems were estimated on the basis of the following operational criteria.

1. The system needed to move a peak load of about 1075 passengers from the parking facility and from the university housing facilities located along its route to the academic zone in not more than thirty minutes.

2. A minimum headway of about two minutes and a maximum of about five minutes are allowed.

3. The system is used from 7:00 a.m. till 6:00 p.m. on average weekdays and from 7:00 a.m. till 12:00 noon on Saturdays when classes are in session, and from 7:30 a.m. to 5:30 p.m. on average weekdays when classes are not in session.

4. The average speed of the bus on the round trip is about eight miles per hour including stops and time allowed between trips.

5. The peak occupancy of the bus is about seventy passengers (25).

On the basis of these criteria and the estimated peak load, thirteen bus units would be needed for each system. The detailed estimates of the requirements of the bus systems and the annual cost of implementing sub-alternative II/3-A appear in Appendix B - section 4.

Sub-Alternative II/3-B. A number of new intraurban
transportation devices are presently being developed and
tried. Questions are often raised as to their efficiency,
economy, and advantages. This sub-alternative used an ele-
vated skybus system to connect the Ross Ade Stadium parking
lot to the academic zone. In this way, the sub-alternative
provided a basis for evaluating the advantages of the de-
vice in meeting future demand for commuting to the academic
zone. The skybus is basically a bus running on an exclusive
elevated roadway. The operation of the system is fully auto-
matic. Its vehicles can be run singly or in trains (26).
The system was selected from among a number of other new
transportation devices (e.g., moving sidewalks and carveyors)
as its operational characteristics were found suitable for
the situation at hand.

Figure 25 shows sub-alternative plan II/3-B. Apart from
the proposed roadway for the elevated skybus system connect-
ing the Ross Ade Stadium parking lot to the academic zone,
all other elements of this plan are identical to those of
sub-alternative II/3-A. In Figure 25, the skybus round trip
is about 2.6 miles long. The requirements of the system were
estimated on the basis of a peak load of 1075 passengers
and according to the following operational criteria:

1. The system should be able to move a peak load of
    about 1075 passengers from the Ross Ade Stadium
    parking lot to the academic zone in not more than
    twenty minutes.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968

FEET
UNIVERSITY BUILDINGS
- - RAILROAD
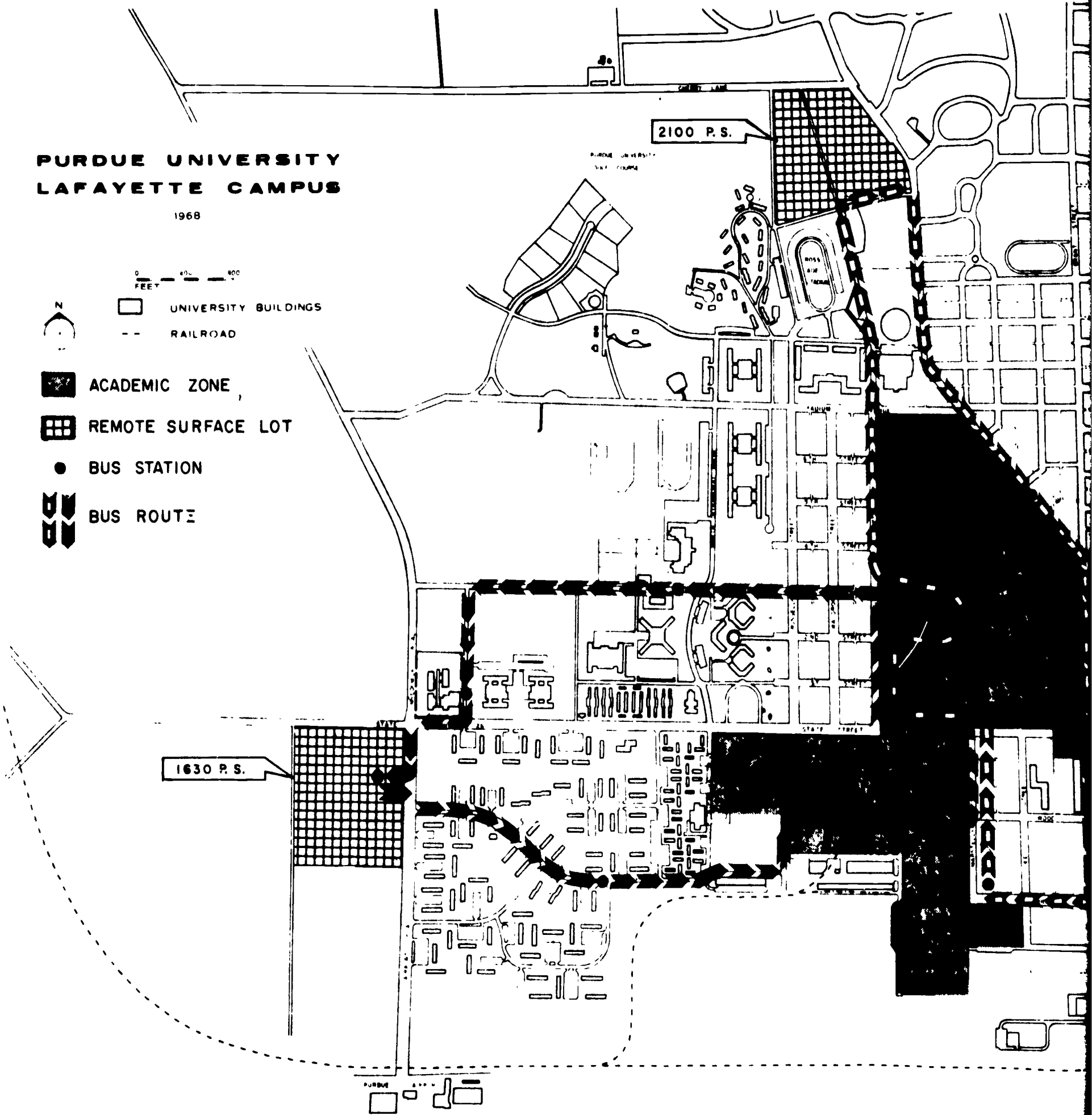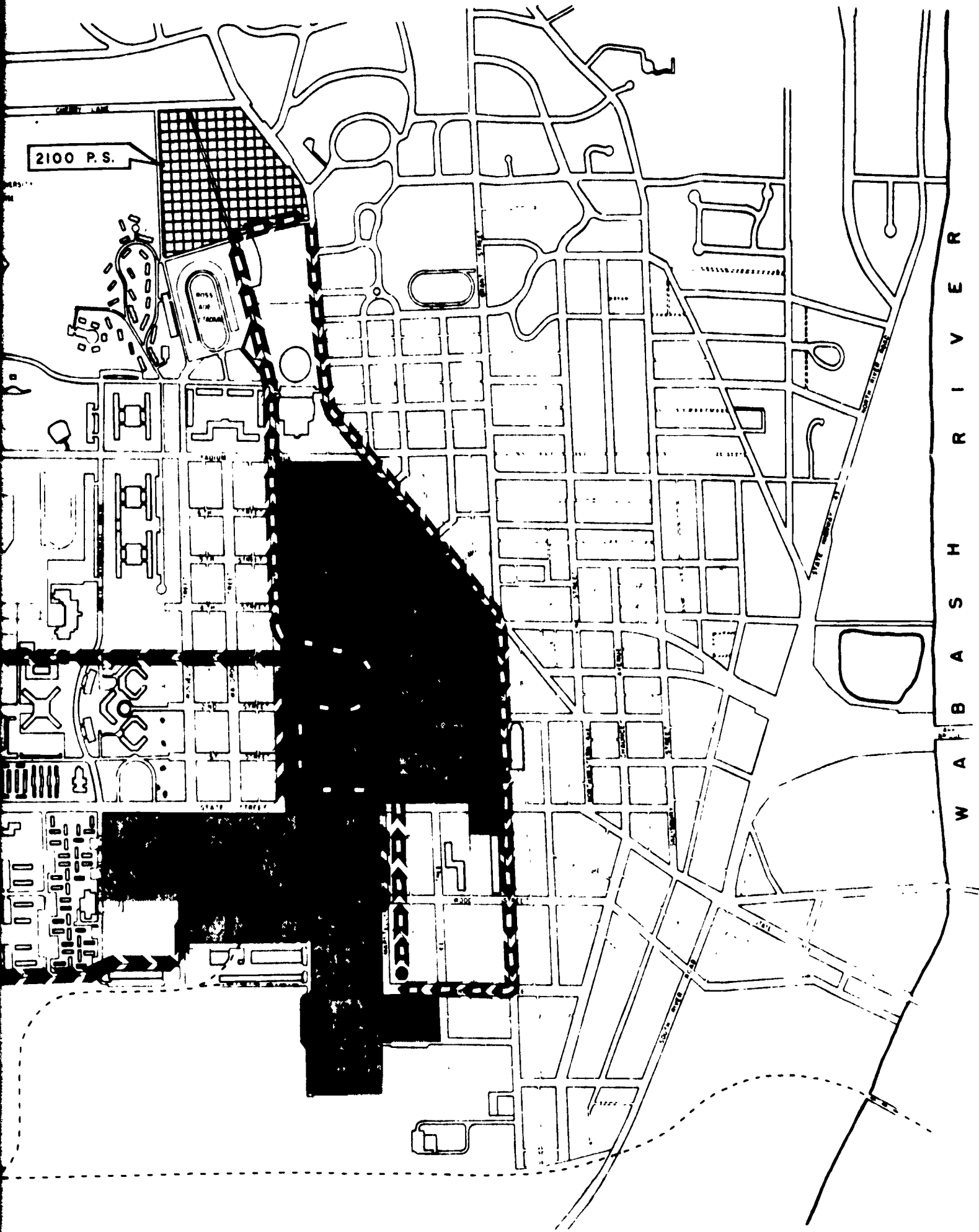
ACADEMIC ZONE
REMOTE SURFACE LOT
BUS STATION
BUS ROUTE

SKYBUS STATION
SKYBUS ROUTE

2100 P.S.

1630 P.S.
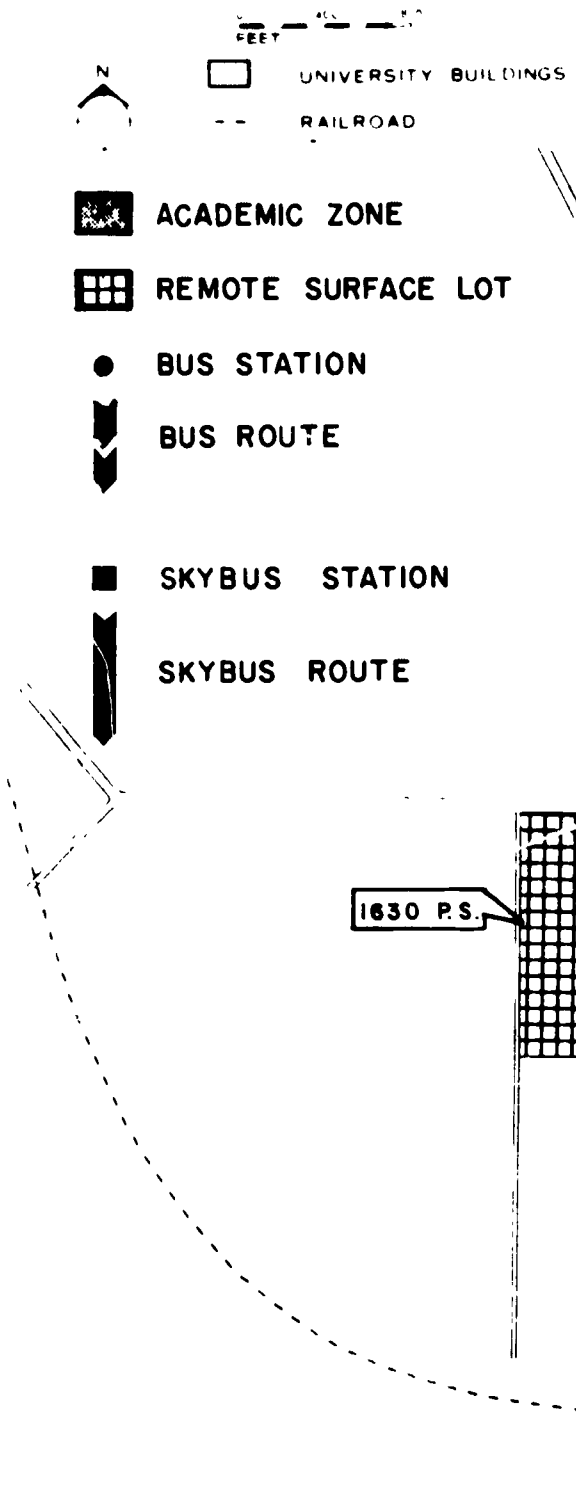
FIGURE 25 - SUB-ALTERNATIVE PLAN II/3-B - (COMMUTING TO A
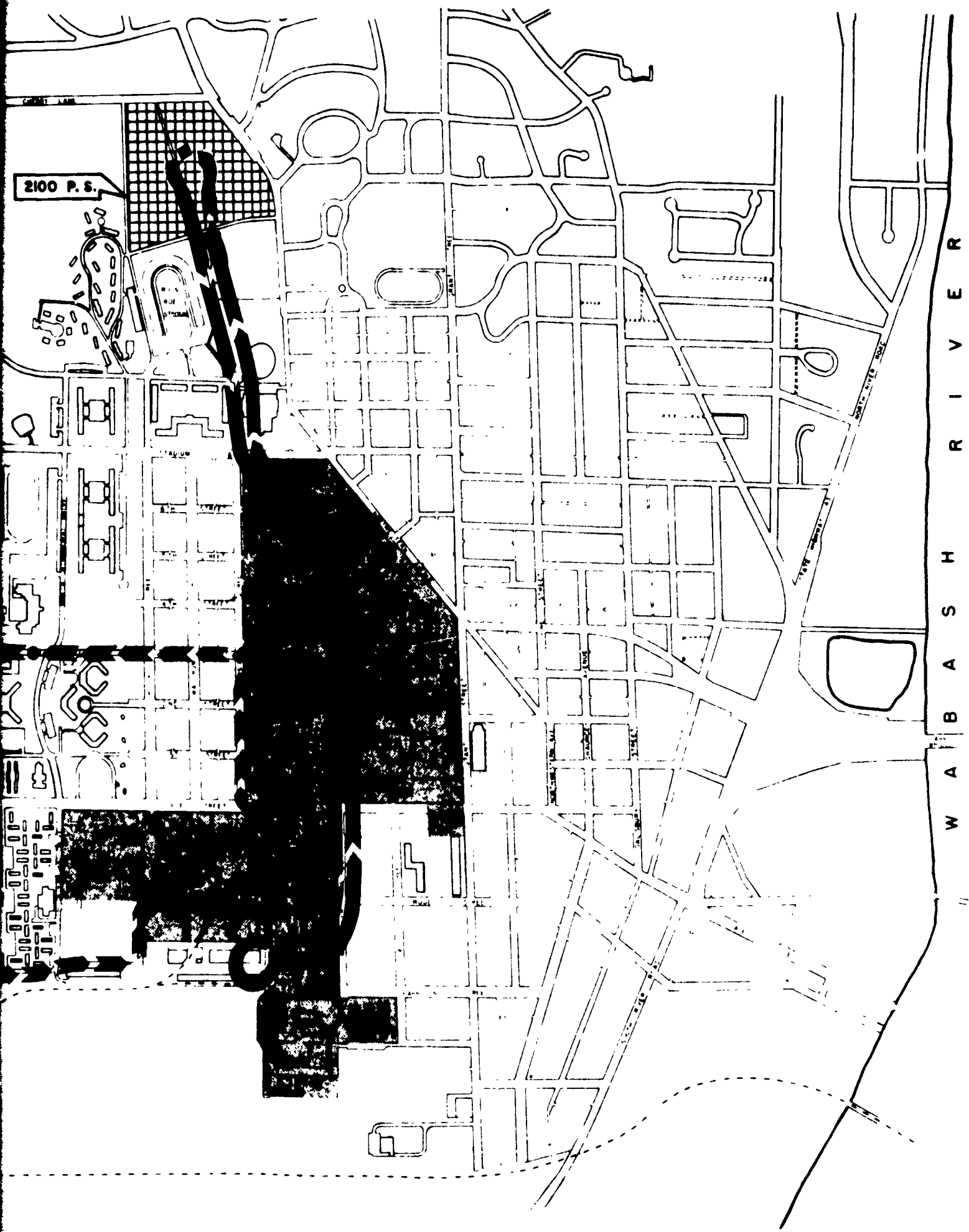
— (COMMUTING TO AND FROM THE ACADEMIC ZONE)

2. A minimum headway of about two minutes and a maximum of about three minutes are allowed.

3. Two vehicles per train are used during peak use and only one during off-peak use.

4. The system is used from 7:00 a.m. to 6:00 p.m. on average weekdays and from 7:00 a.m. to 12:00 noon on Saturdays when classes are in session, and from 7:30 a.m. to 5:30 p.m. on average weekdays when classes are not in session.

5. The average speed of the skybus train is about 25 miles per hour including stops (26).

6. The peak occupancy per vehicle is about 50 passengers (26).

On the basis of these criteria and the estimated peak load, seven skybus vehicles would be needed. The detailed estimates of the requirements of the skybus system and the annual cost of implementing sub-alternative II/3-B appear in Appendix B - section 4.

Evaluation of Alternatives

In the following evaluation, two criteria are considered: convenience and cost. Because continuity in the circulation system, safety, and the potential for developing an aesthetically pleasing environment are about equally satisfactory in each of the alternatives, these criteria were not considered in the evaluation.

Convenience was measured in terms of three factors:

1. the average trip time from parking facilities to
    the academic zone. In estimating these averages,
    the focal point on the academic zone was taken as
    the hypothetical destination of all trips.

2. the average trip time from university housing facil-
    ities to the academic zone (focal point) if the
    mode of transportation is other than walking the
    total distance.

3. the maximum delay expected in bus and skybus trips.
    In bus and skybus systems, headways cannot be re-
    duced below a certain minimum, and vehicle occupan-
    cies cannot be raised above a certain maximum.
    Therefore, a certain period of time is required to
    move all passengers to their destinations during
    the peak hours. This period of time is here re-
    ferred to as the maximum expected delay. Students,
    in order to reach their classes in time, have to
    start their trips from residences early enough to
    allow for at least a portion of this maximum expect-
    ed delay. Obviously, the higher this maximum ex-
    pected delay, the less convenient the system be-
    comes.

The alternatives are also evaluated in terms of their
annual costs. This includes the annual costs of investment
(construction and equipment) as well as the annual costs of

maintenance and operation. The detailed estimates of these annual costs appear in Appendix B. Table 5 gives, for each alternative, the average trip time from parking facilities to the academic zone, the average trip time from university housing facilities to the academic zone, the maximum expected delay, and the estimated annual cost.

In terms of the three measures of convenience used in this evaluation, alternative II/1 appears to be the most convenient, and sub-alternative II/3-A the least convenient. Unlike what is generally believed, the use of the skybus in sub-alternative II/3-B was not as convenient as parking near destinations but was more convenient than the ordinary bus system. The inefficiency of providing intermediate stops along the roadway, however, requires that students living in university housing facilities walk to the terminal point to be able to use the system. Because of this, the system tends to lose one of its basic advantages, namely, high speed for residents of university facilities. From Table 5, it can also be noted that in alternatives II/2 and II/3, the possible maximum delays expected in bus and skybus trips represent a definite inconvenience. This inconvenience is totally absent in alternative II/1 (assuming adequate parking space is provided). In terms of cost, Table 5 shows that sub-alternative II/3-A has the lowest estimated annual cost while sub-alternative II/3-B has the highest. However, alternatives II/1 and II/2 are very close, in annual cost, to alternate II/3-A.

Table 5. Evaluation of Alternative Commuting Plans.

Alternatives	Criteria						Cost
	Average trip time from parking facilities to the academic zone (focal point)		Convenience Average trip time from university housing facilities to the academic zone (focal point)[1]		Maximum delay expected in bus and skybus trips		Estimated annual cost (investment + maintenance and operation)[4] - 1966 dollars.
	Trip time (minutes)	Trip mode	Trip time (minutes)	Trip mode	Delay (minutes)	Trip mode	
Alternative II/1. Parking around the academic zone.	5	on foot	11	by auto then on foot	--	--	$654,250.00
Alternative II/2. Parking around the academic zone and bus system connecting university housing facilities to the academic zone.	5	on foot[2]	20^3	by bus then on foot	18	by bus	$664,186.00
Alternative II/3. Remote parking connected to the academic zone by bus (or skybus) systems. Sub-alternative II/3-A. Remote parking connected to the academic zone by bus systems.	17	on foot then by bus then on foot	20^3	by bus then on foot	30	by bus	$636,114.00
Sub-alternative II/3-B. Remote parking connected to the academic zone by a skybus system and a bus system.	10	on foot then by skybus then on foot	17	on foot then by skybus then on foot	18	by skybus	$982,998.00

[1] excluding pedestrian trips.

[2] for users of parking around the academic zone.

[3] including walking from residence to bus station.

[4] detailed calculations appear in Appendix B.

When the alternatives are evaluated on the basis of
convenience and cost together, it is clear that alternative
II/2 and sub-alternative II/3-B, because of their higher
annual costs and/or lower levels of convenience (in terms
of the three measures indicated above) would rank lower than
alternative II/1 and sub-alternative II/3-A. By limiting
the evaluation to alternative II/1 and sub-alternative II/3-A
(on the grounds of their superiority) and by comparing their
advantages and disadvantages, it can be seen that one offers a
lower annual cost while the other offers a higher level of
convenience. The comparison is obviously one between quant-
ity and quality, and as such, it is objectively unfeasible.
It can be concluded that in order to decide which of the two
alternatives is more appropriate (in terms of the criteria
set above), subjective value has to be assigned to the factor
of convenience. Such an assignment should be made in ac-
cordance with standards and policies adopted by the univers-
ity. The cost of alternative II/1, however, is not much
greater than that of sub-alternative II/3-A while the conven-
ience provided by alternative II/1 is much greater than that
offered by sub-alternative II/3-A. On this basis, it is
expected that alternative II/1 would be selected as the best
plan by most decision-makers.

CHAPTER IV.   CONCLUSIONS AND RECOMMENDATIONS

This study was directed toward the investigation of some aspects of the transportation problems on the Purdue Lafayette campus, the estimation of a number of its future transportation requirements, and the formulation of alternative plans to meet these requirements.   On the basis of the findings of this study, the following conclusions and recommendations appear justified.

Conclusions

1. Based on the opinions of the university faculty and the potential capacity of the existing physical plant, an ultimate future enrollment of about 35,000 students seems reasonable.   It is expected that about 35 percent of this ultimate enrollment would be graduate students and about 26 percent would be married students.   For this ultimate enrollment, it is estimated that the university will employ about 9,450 full-time staff members.

2. On the basis of the envisaged university housing policy and the observed trend of student demand on university housing, it is estimated that, in the future (i.e., when the ultimate enrollment is attained), the university will provide housing for

about 55 percent of the undergraduate single students, 40 percent of the graduate single students, and 40 percent of the married students (graduate and undergraduate).

3. Analysis of the pedestrian circulation in and around the academic zone indicates that:

   a. the existing layout and use of the instructional facilities in the academic zone do not provide conditions of minimum pedestrian movement. A number of instructional facilities with high frequency of use are located on peripheral sites while some conveniently accessible central locations are used for facilities that are not used (or infrequently used) for instruction. This tends to decrease the efficiency of pedestrian circulation in the academic zone.

   b. pedestrian-vehicle conflicts exist and are expected to increase at a number of locations in the academic zone, and especially on State Street. Around the academic zone, pedestrian-vehicle conflicts are expected to significantly increase on University and Russel Streets between First and Third Streets and on Stadium Avenue south of Cary Hall.

4. Four interrelated student population characteristics were found to influence student demand on parking

around the academic zone: (1) size and composition
of student population, (2) daytime population of
students in the academic zone, (3) student behavioral
patterns in using their automobiles to commute to
the academic zone, and (4) the residential distribu-
tion of students on and around the campus.   Fore-
casts were made for these four characteristics for
the future.   The future student demand for parking
around the academic zone was also estimated from these
student population characteristics.   A student park-
ing demand forecasting model thus developed indi-
cated that the student demand for parking around the
academic zone is expected to be about 3,685 parking
spaces for the ultimate enrollment.

5.   On the basis of the observed trend (1963-1967) in the
number of parking spaces per full-time staff member
working in the academic zone, future staff parking
demand was estimated to be about 6,650 parking
spaces.   It was also estimated that 330 parking
spaces will be needed for visitors' use.

6.   It is expected that the parking facilities presently
operated by the university in and around the aca-
demic zone, and an additional 1000 on-street free
parking spaces around the academic zone will remain
in use by commuters in the future.   Thus, a net
additional 4,330 parking spaces will be required

(for the future) to meet the parking demands of
students, staff, and visitors at the time of ulti-
mate enrollment. If these are provided in remote
parking facilities, a bus system would be required
to move the parkers to the academic zone. The peak
load on such a system is estimated to be about 2,150
passengers in a 30-minute period.

7. Of the alternative plans developed to meet the future
demands for commuting to and from the academic zone,
two appear to offer reasonable solutions. In terms
of annual cost, a plan that provides the net future
parking demands of students, staff, and visitors in
surface lots and multi-story garages on close-by lo-
cations around the academic zone (alternative II/1),
would involve an estimated annual cost of about
$654,250.00 An alternative plan that provides the
same future parking demands in two surface lots
located north of Ross Ade Stadium and on the south-
west corner of Airport Road and State Street and
connected to the academic zone by two street bus
systems (sub-alternative II/3-A), would require an
estimated annual cost of about $636,114.00. When
convenience was measured by the average trip time
from parking facilities to the academic zone, by
the average trip time from university housing facil-
ities to the academic zone, and by the maximum delay

expected for bus trips, it was found that the former
offers a much higher level of convenience than the
latter. On the basis of cost and convenience, it
is expected that the former (alternative II/1) would
be selected as the best plan by most decision-makers.

Recommendations

1. To maximize the efficiency of pedestrian circulation
    in the academic zone, it is recommended that:

    a. non-instructional facilities presently occupying
        central locations and having minimal functional
        linkages with other instructional facilities
        (e.g., Engineering Administration building, the
        power plant, and Agricultural Experiment Station)
        be, whenever feasible, relocated to make room
        for future instructional uses.

    b. infrequently used instructional facilities located
        in the central area be put to more intensive use
        in the future (e.g., Pierce Conservatory, Michael
        Golden Shops, and the Aeronautical and Engineering
        Sciences building).

    c. future instructional facilities planned for inten-
        sive use be centrally located (within 1100 feet
        of the focal point) whenever possible.

    d. the possibility of using centrally located facil-
        ities by functions (lecture halls, laboratories,
        offices, etc.) rather than by major field

(Chemistry, Education, Electrical Engineering,
etc.) be investigated as a means of reducing
the number of problematic pedestrian trips
(which cannot be walked within the time-break
allowed between classes).

2. To minimize future pedestrian-vehicle conflicts in
and around the academic zone, it is recommended
that:

a. through vehicular traffic be eliminated on the
north campus.

b. vehicular traffic on Stadium Mall be eliminated
or limited to one way in the south direction.

c. vehicular traffic and curb parking be elimin-
ated on Oval Drive (between Memorial Mall and
State Street), Memorial Mall (between Purdue
Mall and Central Drive), Central Drive (between
the Chemistry building and Stanley Coulter
building) and south of the Hall of Music.

d. an open pedestrian underpass connecting the
north and south campuses be provided under State
Street along the east side of the Home Economics
Administration building.

e. a study be made of the pedestrian-vehicular con-
flicts on State Street resulting from the grad-
uate housing complex south of State Street.

f. provision for separated pedestrian crossing be studied and appropriate traffic controls be used on Russell and University Streets at Second Street to secure safe crossings for the heavy concentrations of pedestrians at these locations

3. It is recommended that the future demands for nonpedestrian commuting to and from the academic zone be met by implementation of adequate plans. On the basis of cost and convenience as analyzed in this study, alternative plan II/1 appears to be best.

LIST OF REFERENCES

LIST OF REFERENCES

1. Jakad, William, "Committee Controls Traffic Step-by-Step," _College and University Business_, Vol. 32, June 1962, pp. 47-52.

2. Educational Facilities Laboratories and Duke University, _Computer Aided Campus Planning_, Educational Facilities Laboratories, New York, New York, 1967.

3. Bartholomew, Harland and Associates, _A Traffic and Parking Analysis, The Ann Arbor Thoroughfare Plan in Relation to University of Michigan Central Campus Study_, University of Michigan, Ann Arbor, Michigan, 1964.

4. Bartholomew, Harland and Associates, _Long-Range Traffic and Parking Plan, University of Mississippi_, University of Mississippi, Mississippi, 1963.

5. Dober, Richard P., _Campus Planning_, Reinhold Publishing Corporation, Cambridge, Massachusetts, 1963.

6. Bartholomew, Harland and Associates, _Long-Range Parking Plan for the University of Illinois_, University of Illinois, Urbana, Illinois, 1962.

7. Marconi, William, "A Study of Parking Needs at Two Urban Campuses," _Traffic Engineering_, Vol. 38, July 1968, pp. 50-51.

8. Pendakur, V. Setty, "Access, Parking, and Cost Criteria for Urban Universities," _Traffic Quarterly_, Vol. 22, July 1968, pp. 359-387.

9. Purdue University, "Student Contact Hours by Type of Instruction by Type of Room," (May 1967 and November 1967), Unpublished Material, Office of Schedule and Space, Purdue University, Lafayette, Indiana.

10. Egner, Anton J., "How Big Can You Get?" _College and University Business_, Vol. 37, November 1964, pp. 57-61.

11. Purdue University, "Enrollment Reports," (for Fall and Spring Semesters during the period 1956-1967), Unpublished Material, Office of the Registrar, Purdue University, Lafayette, Indiana.

12. Jackson, R. W. B., <u>The Problem of Numbers in University Enrollment</u>, Canadian Education Association and the Department of Educational Research, Bulletin No. 18, Canada, 1963.

13. Martin, Warren B., "The Problem of Size," <u>The Journal of Higher Education</u>, Vol. 38, March 1967, pp. 144-152.

14. Purdue University, "Faculty Questionnaire on University Policies Affecting Development of Master Plan of University," Unpublished Material, Purdue University, Lafayette, Indiana, 1968.

15. Purdue University, "Inventory of Total and Assigned Areas Per Building," Unpublished Material, Office of Schedule and Space, Purdue University, Lafayette, Indiana, December 1967.

16. Purdue University, "Statistical Reports," (Fall semesters during the period 1963-1967), Unpublished Material, Comptroller's Office, Purdue University, Lafayette, Indiana.

17. Purdue University, "Student Contact Hours - Each Building by day by Hour," (Fall semesters 1966 and 1967, Spring semesters 1967 and 1968), Unpublished Material, Office of Schedules and Space, Purdue University, Lafayette, Indiana.

18. Purdue University, "Statistical Reports," (1962 through 1967), Unpublished Material, Office of Libraries, Purdue University, Lafayette, Indiana.

19. Purdue University, "Statistical Reports," (1965 through 1967), Unpublished Materials, Foods Department, Purdue University, Lafayette, Indiana.

20. Purdue University, "Ten-Year program of Traffic Facilities for Purdue University," Unpublished Material, Committee on Parking and Movement, Purdue University, Lafayette, Indiana, 1963 (and supplemented in 1964 through 1968).

21. Purdue University, "Number of Students Living in Different Housing Facilities on and Around the Lafayette Campus," Unpublished Material, Dean of Men's Office, Purdue University, Lafayette, Indiana, November 1967.

22. Purdue University, "Statistical Reports," (Fall semesters of 1963 through 1967), Unpublished Material, University Residences' Office, Purdue University, Lafayette, Indiana.

23.   Purdue University, "Student Information," Unpublished
       Material, Data Processing Department, Purdue University,
       Lafayette, Indiana, Spring Semester 1968.

24.   French, David K., "A Simplified Procedure for Major
       Thoroughfare Planning in Small Urban Areas," an
       Unpublished Master Thesis, Civil Engineering School,
       Purdue University, Lafayette, August 1968.

25.   Berry, Donald S., G. W. Blomme, P. W. Shuldiner and
       J. H. Jones, The Technology of Urban Transportation,
       Northwestern University Press, 1967.

26.   MPC Corporation, Report on Testing and Evaluating of
       the Transit Expressway, Allegheny County, Pittsburgh,
       Pennsylvania, 1967.

27.   Michael, H. L.   "Factors in the Economics of Parking
       and Bus Systems," An Unpublished Inter Office Memorandum,
       School of Civil Engineering, Purdue University, Lafayette,
       Indiana, 1968.

28.   Smith, Wilbur and Associates, Parking in the City C nter,
       New Haven, Connecticut, 1965.

29.   Hewes, L. I. and C. H. Oglesby, Highway Engineering,
       John Wiley and Sons, 1954, p. 60, Table 5.

APPENDIX A.   SUMMARY OF RESULTS - FACULTY QUESTIONNAIRE ON
UNIVERSITY POLICIES AFFECTING DEVELOPMENT OF MASTER PLAN
OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

APPENDIX A. SUMMARY OF RESULTS - FACULTY QUESTIONNAIRE ON UNIVERSITY POLICIES AFFECTING
DEVELOPMENT OF MASTER PLAN OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

Please complete the following:

1. My rank is:

    33%(1A) Professor   4% (1D) Instructor
                (323)   (41)
    29%(1B) Associate Professor   3% (1E) Other
                (290)   (27)
    31%(1C) Assistant Professor

2. My primary activity at Purdue is:

    15%(1F) Administration   59%(1H) Teaching
                (144)   (574)
    20%(1G) Research   7%(1I) Other
                (187)   (60)

3. I have been a member of the faculty of Purdue University for:

    38%(1J) Over 10 years   23%(1K) 5 to 10 years   36%(1L) Less than 5 years
                (375)   (222)   (350)

_____
(Name, printed please, optional)

BASE N = 985

4. My principal activity is in the:

23%(2A)   School of Agriculture   (221)

16%(2B)   Schools of Engineering (151)

3%(2C)   School of Home Economics (30)

24%(2D)   School of Humanities, Social Science and Education   (231)

3%(2E)   School of Industrial Administration and Management   (31)

2%(2F)   School of Pharmacy and Pharmacal Sciences   (22)

16%(2G)   School of Science   (156)

5%(2H)   School of Technology   (45)

2%(2I)   School of Veterinary Science and Medicine   (23)

2%(2J)   University Administration   (21)

4%(2K)   Other   (41) _____

5. My principal assignment in the above School is in the following Department (School in Engineering):

_____

_____

ACADEMIC

6. In September 1966, the enrollment on the Lafayette Campus was approximately 21,400 students of which about 16,600 were undergraduates and 4,800 were graduate students. Five years ago, in September 1961, there were approximately 16,500 students of which about 13,400 were undergraduates and 3,100 were graduates. The <u>maximum</u> <u>total</u> of students on the Lafayette Campus should be limited to:

7%(3A)	20,000	12%(3D)	35,000	1%(3G)	50,000
18%(3B)	25,000	5%(3E)	40,000	4%(3H)	Above 50,000
30%(3C)	30,000	1%(3F)	45,000	21%(3I)	Do Not Know

7. Slightly more than 22% of the total students in 1966 were graduate students. In 1961, only about 19% were graduate students. Of the maximum total enrollment checked in Question 1, <u>graduate enrollment</u> should be limited to no more than:

8%(4A)	20%	16%(4D)	50%	0%(4G)	80%
32%(4B)	30%	3%(4E)	60%	5%(4H)	Above 80%
19%(4C)	40%	1%(4F)	70%	15%(4I)	Do Not Know

8. The standards for admission of undergraduate students in your school should be:

0%(5A)	substantially lowered	35%(5D)	slightly raised
2%(5B)	slightly lowered	9%(5E)	substantially raised
44%(5C)	left unchanged	8%(5F)	Do Not Know

113

9. The standards for admission of graduate students in your school should be:

    0%(5G) substantially lowered   28%(5J) slightly raised

    3%(5H) slightly lowered   8%(5K) substantially raised

    50%(5I) left unchanged   9%(5L) Do Not Kncw

10. List any specific suggestions you have regarding changes in admission policies for undergraduate and for graduate students (use additional sheet if more space is required).

11. Do you believe any new academic schools or departments should be established on the Lafayette Campus within the next ten (10) years?

    14%(6A) No   38%(6B) Yes   44%(6C) Do Not Know

    If yes, list below in priority order the names of such schools or departments:

12. For optimum development of your Department (School, in Engineering), how many undergraduate students should be enrolled in your department by 1976-77?

    4%(6D) less students than enrolled in 1966-67

    12%(6E) about the same number as enrolled in 1966-67

    17%(6F) slightly more students than enrolled in 1966-67

    17%(6G) 1.5 times the number enrolled in 1966-67

    16%(6H) 2 times the number enrolled in 1966-67

12. Continued.

6% (6I)   3 times the number enrolled in 1966-67

6% (6J)   more than 3 times the number enrolled in 1966-67

19% (6K)   Do Not Know

13. Same as Question 12 but for graduate students in your Department:

3% (7A)   less students than enrolled in 1966-67

10% (7B)   about the same number as enrolled in 1966-67

18% (7C)   slightly more students than enrolled in 1966-67

19% (7D)   1.5 times the number enrolled in 1966-67

20% (7E)   2 times the number enrolled in 1966-67

7% (7F)   3 times the number enrolled in 1966-67

6% (7G)   more than 3 times the number enrolled in 1966-67

15% (7H)   Do Not Know

14. For optimum development of your Department (School, in Engineering), by 1976 the size of the staff (faculty plus clerical and service) should be:

0% (8A)   less than in 1966-67

5% (8B)   about the same as in 1966-67

24% (8C)   slightly more than in 1966-67

30% (8D)   1.5 times the number in 1966-67

14. Continued.

19%(8E) 2 times the number in 1966-67

6%(8F)   3 times number in 1966-67

5%(8G)   more than 3 times the number in 1966-67

8%(8H)   Do Not Know

15. Do you feel that the major facilities and/or equipment now available in your Department are adequate for current teaching needs.

64%(8I) No   31%(8J) Yes

If no, please list the major facilities and/or equipment needed.

16. Some departments schedule large sections for teaching undergraduates. For the teaching of undergraduate freshmen and sophomores in the future in my Department:

18%(9A). no large sections should be used

25%(9B) very few large sections should be used

24%(9C) about the current number of large sections should be used

11%(9D) slightly more large sections should be used

4%(9E)   substantially more large sections should be used

13%(9F) Do Not Know

17. For the teaching of undergraduate <u>juniors and seniors</u> in the future in my Department:

35%(9G) no large sections should be used

25%(9H) very few large sections should be used

18%(9I) about the current number of large sections should be used

6%(9J) slightly more large sections should be used

2%(9K) substantially more large sections should be used

9%(9L) Do Not Know

18. For the teaching of <u>graduate students</u> in the future in my Department; class sizes typically:

10%(10A) should be no more than 10

22%(10B) should be no more than 15

25%(10C) should be no more than 20

18%(10D) should be no more than 25

12%(10E) could be more than 25

9%(10F) Do Not Know

19. Do you believe that major changes in methods of teaching will occur in your Department by 1976?

30%(10G) No   45%(10H) Yes   22%(10I) Do Not Know

If <u>Yes</u>, please state major changes you anticipate will occur.

20. Relative to present usage, to what extent will the following educational equipment or aids be used in 1976 in your Department?

	Increase Considerably	Increase Slightly	No Change	Decrease	Do Not Know
a. Instructional Television	30%(11A)	29%(11B)	19%(11C)	2%(11D)	16%(11E)
b. Computer-assisted Instruction	32%(11F)	25%(11G)	16%(11H)	0%(11I)	19%(11J)
c. Films, Slides, Filmstrips	28%(12A)	35%(12B)	21%(12C)	1%(12D)	10%(12E)
d. Audio Tapes	22%(12F)	28%(12G)	26%(12H)	1%(12I)	15%(12J)
e. Computerized Test Scoring and Analysis	27%(13A)	31%(13B)	20%(13C)	1%(13D)	15%(13E)
f. Tele-lectures (remote audio)	18%(13F)	27%(13G)	26%(13H)	1%(13I)	22%(13J)
g. Graphics, Models	19%(14A)	35%(14B)	24%(14C)	2%(14D)	15%(14E)

21. Relative to present operations, in 1976 what will be the requirements for local production of TV and film instruction materials?

	Increased Greatly	Increased Slightly	No Change	Decreased	Do Not Know
TV	32%(15A)	29%(15B)	12%(15C)	1%(i5D)	23%(15E)
Film	24%(15F)	31%(15G)	15%(15H)	2%(15I)	23%(15J)

RESEARCH

22. Considering current research assignments in your Department, do you expect that the average porportion of faculty research time to teaching time by 1976-77 will:

3%(16A)   substantially decrease

7%(16B)   slightly decrease

39%(16C) stay about the same

26%(16D) slightly increase

14%(16E) substantially increase

8%(16F)   Do Not Know

23. Considering current research assignments in your Department, do you believe that the average proportion of faculty research time to teaching time by 1976-77 should:

5%(16G)   substantially decrease

12%(16H) slightly decrease

35%(16I) stay about the same

25%(16J) slightly increase

16%(16K) substantially increase

5%(16L)   Do Not Know

24. Are there areas in which your Department does not have a current significant re-search program but in which such a program should be developed within the next ten years?

15%(17A) No   54%(17B) Yes   25%(17C) Do Not Know.

If Yes, please list in priority order a brief descriptive name of these areas.

25. Do you feel that the research policies now maintained by the University are satisfactory?

27%(17D) No   43%(17E) Yes   26%(17F) Do Not Know

If No, please briefly state specific policies you feel should be adopted.

26. In addition to the major new facilities and/or equipment which you listed under Question 15 of the ACADEMIC portion of this survey, are there other major new facilities and/or equipment which should be furnished for research purposes by the University?

12%(17G) No   40%(17H) Yes   42%(17I) Do Not Know

If Yes, please list the major new facilities and/or equipment needed.

CONTINUING EDUCATION

27. The programs of continuing education (evening courses, short conferences, open seminars, etc.) currently vary by departments. On the basis of the current continuing education activity of your Department, the program offered by your Department on the Lafayette Campus should:

3%(18A) be substantially decreased   28%(18D) be slightly increased

3%(18B) be slightly decreased   25%(18E) be substantially increased

24%(18C) remain about as at present   13%(18F) Do Not Know

31. In September 1966, 32% of the single graduate men and 41% of the single graduate women or a total of 35% of the single graduate students elected to live in the Graduate House and 250 "overflow" spaces made available in the residence halls.

On the basis of this current demand and your estimate of University growth, the proportion of single graduate students housed in University operated Graduate Houses in the future should be:

3%(20A)   substantially decreased
3%(20B)   slightly decreased
15%(20C) maintained at the present level
29%(20D) slightly increased
32%(20E) substantially increased
17%(20F) Do Not Know

32. Out of the total enrollment of 21,407 undergraduate and graduate students in September 1966, 3,003 men and 1,001 women were registered as married students. The University accommodated 28.4% of these 4,004 married students in University operated apartments.

On the basis of the current use and your estimate of University growth, the pro-portion of married students housed in University operated apartments in the future should be:

4%(20G)   substantially decreased
4%(20H)   slightly decreased
15%(20I) maintained at the present level
26%(20J) slightly increased
38%(20K) substantially increased
13%(20L) Do Not Know

33. The University currently has some housing facilities which it makes available as rental housing to new faculty members for a maximum of two years. The University should:

4%(21A)   not assist new faculty members with their housing needs

33. Continued.

91%(21B) assist new faculty members with their housing needs

3%(21C) Do Not Know

If you feel the University should assist new faculty members with their housing needs, please answer the following:

61%(21D) the present policy of some University rental units for a maximum of two years is satisfactory.

26%(21E) the present assistance policy is inadequate.

If you think the present policy is inadequate, please state how you feel the University should provide such housing assistance.

CULTURAL ACTIVITIES AND RECREATION

34. Do you believe the cultural activities currently available at the Lafayette Campus are adequate?

26%(21F) No   66%(21G) Yes   5%(21H) Do Not Know

If No, please state what cultural activities you would like to see increased or developed.

35. Some support has been noted for a campus facility in which the visual arts (sculpture, paintings, etc.) of the University could be displayed. Do you favor such a campus facility?

17%(21I) No   68%(21J) Yes   13%(21K) Do Not Know

36. Should the University have a formal faculty club facility?

15%(22A) No   72%(22B) Yes   10%(22C) Do Not Know

37. If your answer to 36 is Yes, would you join such a club if it did not have a liquor privilege?

25(22D) No   48%(22E) Yes

38. If your answer to 36 is Yes, would you join such a club if it did have a liquor privilege?

8%(22F) No   61%(22G) Yes

39. Supposing that such a facility were to be realized, would you support it if it were located:

On the campus 70%(23A) Yes   19%(23B) No

Adjacent to the campus with adequate parking 76%(23C) Yes   14%(23D) No

Within 3 miles of the campus with adequate parking 56%(23E) Yes   31%(23F) No

40. Would you prefer such a club to provide (choose one)

2%(23G) Lounge, recreational facilities, meeting rooms but no food services

16%(23H) Lounge, recreational facilities, meeting rooms plus a luncheon service

71%(23I) Lounge, recreational facilities, meeting rooms, luncheon service and dinner

41. What is the maximum membership fee you would be willing to pay to become a member of a faculty club, assuming that you would be able to purchase food services at prices equivalent to those for similar services in the Union, said membership fee to be deducted monthly from your salary, in ten equal payments?

22%(24A) none   48%(24B) $10 a month

17%(24C) $15 a month   5%(24D) $25 a month

42. If you are willing to pay a fee, should the membership fees vary by rank of faculty member, i.e., a lower fee for an assistant professor than for a full professor?

44%(24E) No   37%(24F) Yes

43. Should membership be extended to:

64%(24G) Faculty only

11%(24H) Alumni

16%(24I) Friends of the University

4%(24J) Other (Please specify) _____

44. One method of financing a facility for a faculty club is to sell shares later to be amortized or sold. Would you subscribe to this opportunity if the amount per share were

59%(25A) I would not subscribe   28%(25B) $500   2%(25C) $1000

45. Please list any other comments you have regarding the establishment of a faculty club.

CAMPUS BEAUTIFICATION

46. Do you find the overall design, architecture, and landscaping of the Lafayette Campus to be:

19%(25D) Very poor

23%(25E) Poor

32%(25F) Fair

19%(25G) Good

6%(25H) Very good

1%(25I) Do Not Know

47. Assuming that sufficient parking space could be constructed adjacent to the campus on its perimeter, would you advocate that major areas on the campus now devoted to parking be developed as landscaped greensward?

30%(25J) No   59%(25D) Yes   8%(25L) Do Not Know

48. Assuming that adequate parking is constructed on the perimeter of the campus, should all motor vehicle traffic, except necessary service and delivery vehicles, be barred from the central campus?

37%(26A) No   49%(26B) Yes   7%(26C) Do Not Know

59. Please list any suggestions you have for future development relative to the design architecture, and landscaping of the Lafayette Campus.

OTHER

50. Considering the various services now provided by the University (photographic, duplicating, computing, machine shop, campus mail, transportation, etc.), do you know of services not now provided which will be required by 1976?

77%(26D) No   18%(26E) Yes

If Yes, please list them in order of priority.

51. Do you find all of the various services now provided to be adequate?

    41%(26F) No   50%(26G) Yes

    If No, please state the improvements needed.

52. Do you know of any of the adequate services now provided which will need to be expanded greatly during the next ten years (expanded substantially more than that dictated by University growth)?

    67%(26H) No   22%(26I) Yes

    If Yes, please list them and note amount of expansion required and why.

53. The current University policy is to provide in all new construction an individual air conditioned office of 120 square feet for each full time faculty member with academic rank of instructor and above. This amount of space is:

    1%(27A) substantially more than required

    4%(27B) slightly more than required

    55%(27C) about right

    23%(27D) slightly less than required

    9%(27E) substantially less than required

    4%(27F) Do Not Know

54. The Varsity Athletic Program of the University currently emphasizes football and basketball and provides programs in several additional areas. Do you feel any changes are desirable in the Varsity Athletic Program within the next ten years?

    39%(27G) No   27%(27H) Yes   28%(27I) Do Not Know

    If Yes, please state the changes you feel to be desirable.

55. Please list any other comments you have relative to any matter which would affect the updating of the Master Plan of physical facilities of the Lafayette Campus. (Attach as many pages as necessary).

Your cooperation in completing this detailed questionnaire is most appreciated. It is a real way for you to contribute to the planning of the Lafayette Campus.

APPENDIX B. ALTERNATIVE COMMUTING PLANS -
ESTIMATED ANNUAL COSTS

APPENDIX B.   ALTERNATIVE COMMUTING PLANS -
ESTIMATED ANNUAL COSTS

This appendix comprises four sections:

1.   Estimated annual costs of different types of park-
ing facilities (per parking space).

2.   Alternative II/1 - estimated annual cost.

3.   Alternative II/2 - estimated annual cost.

4.   Alternative II/3 - estimated annual cost.

Investment costs (constructions and equipment) are based
on information as of 1966. Annual costs of investment are
estimated on the basis of an interest rate of 5.25 percent
and according to the expected economic life time of the item
under consideration. Average total annual cost includes both
investment cost and maintenance and operation costs.

Section 1 - Estimated Annual Costs of Different Types
of Parking Facilities (Per Parking Space)

The following is a comparison between the estimated
annual costs of providing parking spaces in different types
of facilities. The estimates are made according to the
following assumptions:

1.   Parking facilities provided on land owned by Purdue
University require no expenditures for land
acquisition.

2. Cost of land in the first row of blocks around the academic zone is about $4.00 per square foot (as of 1966) (27).

3. Above ground garages are four-stories high.

4. One parking space in a four-story garage needs about 100 square feet of land area (28).

5. One parking space in a surface parking lot needs about 300 square feet of land area (27).

Parking in Underground Garages on University Owned Land - Annual Cost Per Parking Space.

- economic life   = 40 years   (27)
- cost of construction   = $4,000.00   (27)
- cost of land   = $--------
- total cost of investment   = $4,000.00
- capital recovery factor   = .060325   (29)
- annual cost of investment   = $ 241.00
- annual cost of maintenance and operation= $ 100.00   (27)
- annual cost (total)   = $ 341.00

Parking in Four-Story Garages on Non-University Owned Land - Annual Cost Per Parking Space.

- economic life   = 40 years   (27)
- cost of construction   = $1,500.00 (27)
- cost of land   = $ 400.00
- total cost of investment   = $1,900.00
- capital recovery factor   = .060325   (29)

- annual cost of investment   = $ 115.00

- annual cost of maintenance and operation= $ 50.00 (27)

- annual cost (total)   = $ 165.00

Parking in Surface Lots on Non-University Owned Land - Annual Cost Per Parking Space.

- economic life   = 20 years   (27)

- cost of construction   = $ 300.00

- cost of land   = $1,200.00

- total cost of investment   = $1,500.00

- capital recovery factor   = .08197   (29)

- annual cost of investment   = $ 123.00

- annual cost of maintenance and operation= $ 50.00 (27)

- annual cost (total)   = $ 173.00

Parking in Surface Lots on University Owned Land - Annual Cost Per Parking Space.

- economic life   = 20 years   (27)

- cost of construction   = $ 300.00 (27)

- cost of land   = $--------

- total cost of investment   = $ 300.00

- capital recovery factor   = .08197   (29)

- annual cost of investment   = $ 24.60

- annual cost of maintenance and operation= $ 50.00 (27)

- annual cost (total)   = $ 74.60

Section 2 - Alternative II/1 - Estimated Annual Cost

Future parking demand was estimated to be 3,685 parking spaces for students, 6,650 for staff, and 330 for visitors. Of these, the university presently (1968) provides 5,633 parking spaces and about 1,000 on-street parking spaces are assumed to remain available in the future. The present parking supply will be reduced by 302 parking spaces due to the proposed changes in the academic zone. Therefore, the net number of parking spaces which should be added in the future is about 4,330 parking spaces. In this alternative, an additional 315 parking spaces presently provided in parking lots will be removed upon construction of the proposed multi-story garages. Therefore, the net additional parking demand in this alternative is about 4,650 parking spaces.

Annual Cost. In alternative II/1, 1,250 parking spaces are provided as surface parking on university owned land and 3,400 parking spaces are provided in four-story above ground garages on non-university owned land.

According to Appendix B - Section 1, the annual cost of providing these numbers and types of parking spaces is estimated to be 1,250 x 74.60 + 3,400 x 165.00 = $654,250.00.

Section 3 - Alternative II/2 - Estimated Annual Cost

In this alternative, the street bus system provided between university housing facilities and the academic zone (Figure 23) will have to carry an estimated peak load of about 430 students around 8:30 a.m. On the basis of the

operational criteria outlined in the description of this alternative in the text, the annual cost of providing this bus system is estimated as follows:

- economic life of bus units $\qquad$ = 12 years (27)

- capital cost per bus unit $\qquad$ = $30,000.00 (27)

- capital recovery factor $\qquad$ = 0.11785 (29)

- annual cost of investment per bus unit = $ 3,536.00

- mileage per bus unit per year =
  13.75 daily trips x 196.2 full days
  x 5.00 miles per trip = 13,481 miles
  to this mileage, 10 percent is added to
  provide for necessary non-assigned trips

- total mileage per bus unit per year $\qquad$ = 14,829 miles

- cost of maintenance and operation = $ 0.65 (27)
  per vehicle mile

- annual cost of maintenance and operation
  per bus unit = 14,829 x 0.65 = $ 9,639.00

- annual cost per bus unit (investment +
  maintenance and operation) = 3,536.00 +
  9,639.00 = $13,175.00

- number of bus units needed = 8 + one
  additional unit in maintenance or
  repair = 9 bus units

- annual cost of the bus system (total)
  = 8 x 13,175.00 + 3,536.00 = $108,936.00

On the other hand, if the bus system were not used, it would have required 600 additional parking spaces around the academic zone (the number of spaces expected to be used by students living in university housing facilities). If these spaces were provided in four-story garages on non-university owned land, they would have cost about 600 x 165.00 = $99,000.00.

The estimated annual cost of providing all the future parking demand around the academic zone (alternative II/1) is $654,250.00. If the bus system is used, the total parking demand around the academic zone will be reduced by 600 spaces. This means that the annual cost of providing the rest of the parking demand around the academic zone would be about $654,250.00 - 99,000.00 = $555,250,00. This total cost would have been higher if the substituted parking spaces were provided in surface parking on university owned land.

Accordingly, the annual cost of alternative II/2 is estimated to be about 555,250.00 + 108,936.00 = $664,186.00.

Section 4 - Alternative II/3 - Estimated Annual Cost

In this alternative, the two remote parking facilities are connected to the academic zone by two street bus systems in sub-alternative II/3-A and by a combination of a skybus system (from the Ross Ade Stadium parking lot) and a street bus system (from the Airport Road parking lot) in sub-alternative II/3-B. The annual costs of the parking facilities, the street bus systems, and the skybus system are here estimated separately. The annual costs of sub-alternatives II/3-A and II/3-B are then obtained.

Annual Cost of Parking Facilities. According to Appendix B - section 1, the annual cost of providing 3,730 parking spaces in remote parking lots on university owned land = 3,730 x 74.60 = $278,258.00.

<u>Annual Cost of the Street Bus Systems</u>. The two bus systems connecting the Ross Ade Stadium parking lot and the Airport Road parking lot to the academic zone are almost identical in load and round trip length. The estimates of the annual costs are thus made per system and on the basis of the operational criteria outlined in the description of sub-alternative II/3-A in the text.

- economic life of bus units   = 12 years   (27)

- capital cost per bus unit   = $30,000.00   (27)

- capital recovery factor   = 0.11785   (29)

- annual cost of investment per bus unit   = <u>$ 3,536.00</u>

- mileage per bus unit per year = 19.30
  daily trips x 196.20 full days x 3.20
  miles per trip (classes in session) +
  13.20 daily trips x 80.00 full days
  x 3.20 miles per trip (classes not in
  session)   = 15,496 miles
  to this mileage, 10 percent is added
  to provide for necessary non-assigned
  trips.

- total mileage per bus unit per year   = 17,046 miles

- cost of maintenance and operation
  per vehicle mile   = $ 0.65   (27)

- annual cost of maintenance and
  operation per bus unit = 17,046 x 0.65   = <u>$11,080.00</u>

- annual cost per bus unit (investment
  + maintenance and operation) =
  3,536.00 + 11,080.00   = $14,616.00

- number of bus units needed per system
  = 12 + one additional unit in main-
  tenance or repair   = 13 bus units

- annual cost per bus system
  (total) = 12 x 14,616.00 + 3,536.00   = <u>$178,928.00</u>

Annual Cost of the Skybus System. In sub-alternative
II/3-B, the skybus system is used to co⁻⁻ct the Ross Ade
Stadium parking lot to the academic zone. On the basis of
the operational criteria outlined in the description of this
sub-alternative in the text, its average total annual cost
is here estimated according to information provided by the
manufacturer (26).

- economic life of roadway and control
  equipment   = 40 years

- cost of roadway construction and
  control equipment:
  - at grade station   = $ 727,280.00
  - three aerial stations   = $2,031,840.00
  - roadway construction:
    . curved single track - at
      grade (1300 feet)   = $ 100,724.00
    . curved single track - aerial
      (1700 feet)   = $ 321,300.00
    . straight double track - aerial
      (5400 feet)   = $1,382,400.00
    . total cost of roadway (includ-
      ing engineering and administra-
      tion)   = $2,020,954.00

  - one transfer table   = $ 43,503.00
  - heating installation   = $ 76,740.00
  - automatic train operation system   = $ 165,876.00
  - power system   = $ 512,118.00
  - facilities for maintenance and
    repair (to handle 10 vehicles)   = $ 23,448.00
  - audio and visual system   = $ 47,334.00
  - spare parts   = $ 100,000.00
  - total cost of investment for
    roadway construction and control
    equipment   = $5,749,093.00

- capital recovery factor (for roadway
  and equipment)   = 0.060325   (29)

- annual cost of investment for roadway
  construction and control equipment   = $ 346,814.00

- economic life of vehicles   = 20 years

- capital cost per vehicle   = $ 93,910.00

- capital recovery factor (for vehicles) = 0.08197 (29)

- annual cost of investment per vehicle   = $ 7,698.00

   - mileage per vehicle per year =
    44.00 daily trips x 196.20 full
    days x 2.60 miles per trip (classes
    in session) + 35.30 daily trips x
    80.00 full days x 2.60 miles per
    trip (classes not in session)   = 29,788 miles

   - cost of maintenance and operation
    per vehicle mile   = $ 0.70

   - annual cost of maintenance and
    operation per vehicle =
    29,788 x 0.70   = $ 20,852.00

   - annual cost per vehicle (investment
    + maintenance and operation) =
    7,698.00 + 20,852.00   = $ 28,550.00

   - number of vehicles needed = 6 + one
    additional vehicle in maintenance
    or repair   = 7 vehicles

   - annual cost of vehicles = 6 x
    28,550.00 + 7,698.00   = $178,998.00

   - annual cost of the skybus system
    (roadway, control equipment, and
    vehicles) = 346,814.00 +
    178,998.00   = $525,812.00

Annual Costs of Sub-alternatives II/3-A and II/3-B. On

the basis of the above estimates,

   - annual cost of sub-alternative
    II/3-A = 278,258.00 + 2
    x 178,928.00   = $636,114.00

   - annual cost of sub-alternative
    II/3-B = 278,258.00 + 525,812.00
    + 178,928.00   = $982,998.00