TRANSPORTATION STUDY OF CHRISTOPHER CITY

by

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STATEMENT BY AUTHOR

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ABSTRACT

This thesis is the outcome of a study done on the transportation problem of the residents of Christopher City. The problem of the residents of this married-students' housing complex is poor accessibility to the University campus.

The purpose of the study is to determine the University-oriented travel of Christopher City residents and to propose a feasible mass transportation system to satisfy the travel needs. The thesis contains a discussion of the mail survey used to obtain the necessary information. Alternative modes of mass transportation are analyzed. As a result of a decision process, the present bus system operated by the Tucson Transit Corporation is recommended for patronization with a 50 percent subsidy provided by the University. Finally, specific applications of the conclusions for this thesis are suggested for other related situations. In addition, proposed studies are recommended to refine the information used in this thesis.

CHAPTER I

INTRODUCTION

This thesis is a report on the transportation study of Christopher City. From results of a questionnaire survey of the campus trip characteristics of the residents, the travel pattern was established and a means of transportation proposed. Following below is a description of the reviewed group and the objective of the study.

Christopher City

The University of Arizona maintains as part of its housing facilities an off-campus married student apartment complex. This complex, called Christopher City, consists of 420 efficiency, one, and two bedroom apartments. There are approximately 1100 residents during the school year.

As mentioned previously, Christopher City is situated off campus. It is located north of the University at the outskirts of Tucson (see Figure 1). The road distance from the complex to the University is approximately 5.8 miles[1] by way of Campbell Avenue and Fort Lowell Road. If automobiles are used as transportation to the campus, the residents must contend with other commuting students for parking space.

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[1]From the housing office to the Student Union building.

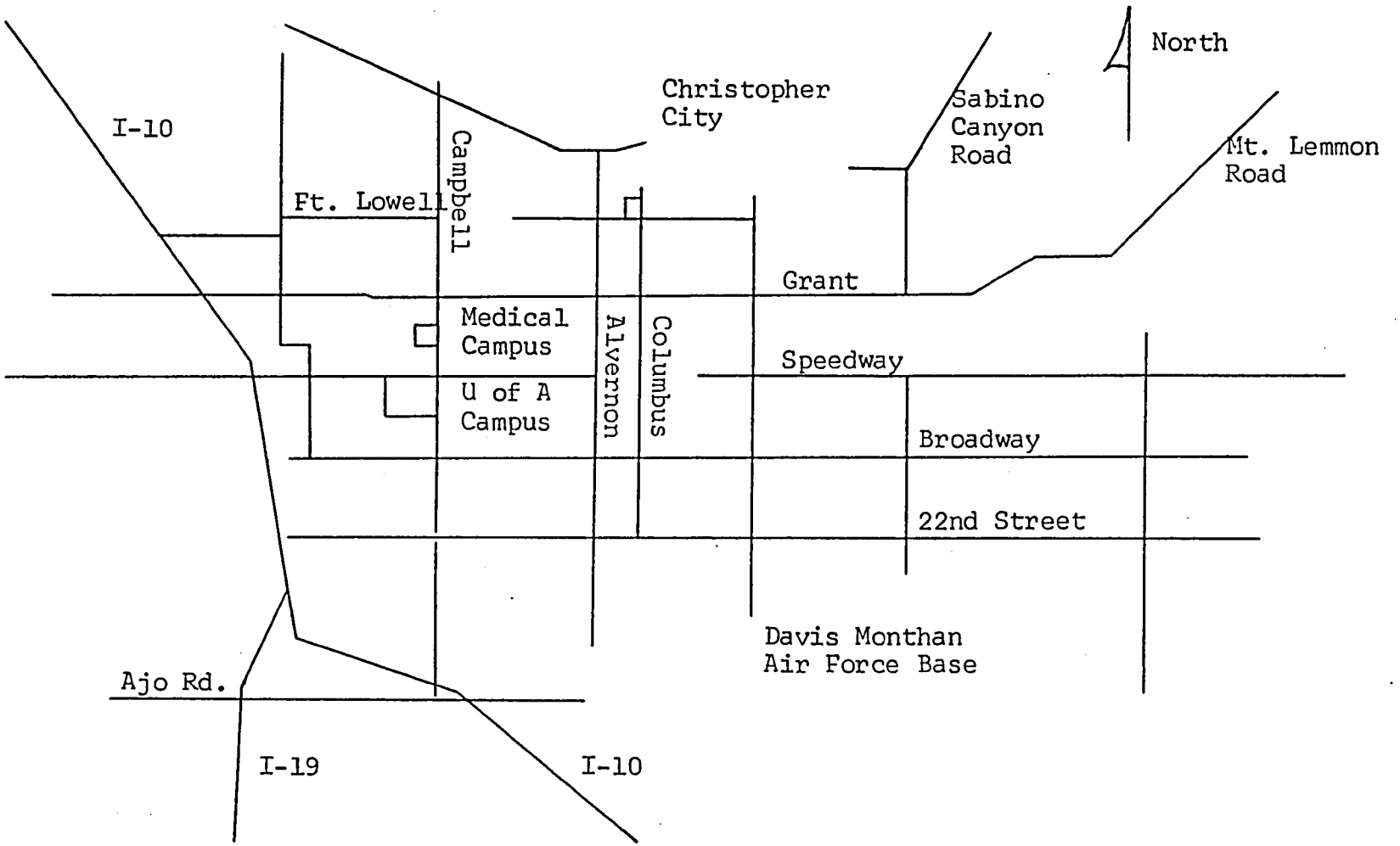

Figure 1. Location of Christopher City

Another, but less commonly used, means of transit is the city's bus system. This transit service is operated by the Tucson Transit Corporation and is subsidized by the City of Tucson. Figure 2 illustrates the routes in Tucson serviced by this transit system. Route 1 is the only direct, non-transfer line from Christopher City to the main campus of the University. Route 11 also serves Christopher City but goes to the El Con shopping center. During the school year of 1971-72, the hourly bus service commenced operations at 6:00 a.m. and ended at 6:10 p.m., Monday through Saturday.

Purpose of Study

The transportation dilemma of Christopher City residency, as invariably expressed by its occupants, is the poor accessibility to the University campus. The remoteness of the housing development virtually necessitates the use of motorized transportation.[2] The student residents must choose between using their own vehicles or commuting on the public transit system.

If the first alternative is selected, the drivers are faced with the traffic congestion and the parking space shortage at the campus--and often more than once a day. In addition, a husband or wife in a one-car family cannot use the car while the other spouse leaves it sitting idle on campus. If the bus mode is chosen for

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[2]Some students, however, do enjoy the opportunity to acquire physical exercise with the use of a bicycle.

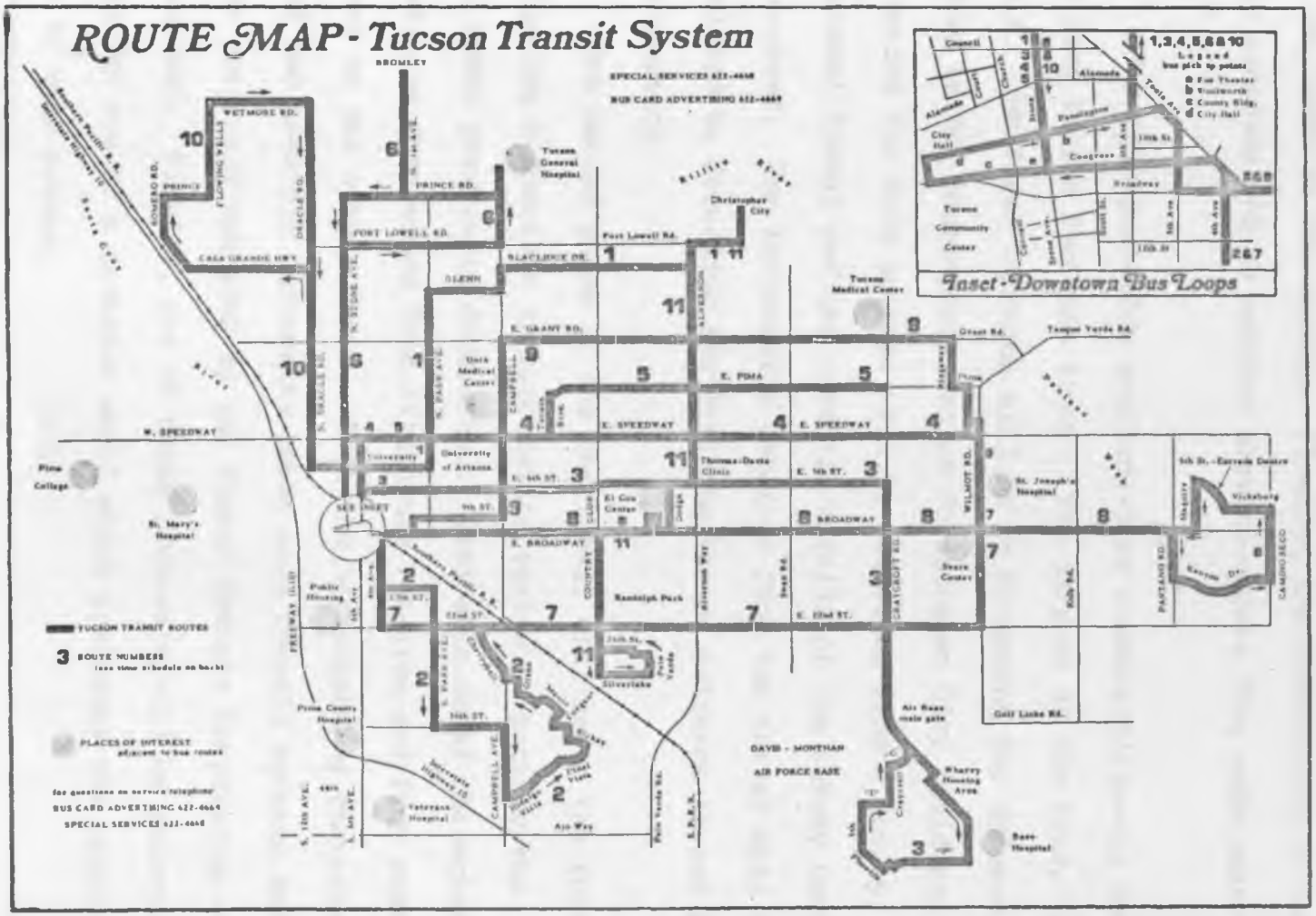

Figure 2. Routes Serviced by Tucson Transit Corporation

the campus trips, the residents are subjected to the discomforts and unreliability of archaic vehicles. Furthermore, the residents view the fares as too costly. Finally, the infrequency of service--hourly schedule and no evening service--makes this mode unattractive.[3]

The transportation problem--poor accessibility--is the underlying reason for this study. The purpose of the study is twofold. The first function will be to determine the University-oriented travel characteristics of Christopher City residents. The data needed for this purpose will be collected from a survey. Both the general format and the specific details of the survey used will be discussed. The information obtained from the survey will then be analyzed to determine the existing travel patterns to and from the University.

The second phase of the the thesis will serve the function of proposing a feasible transportation system to satisfy the travel needs previously determined. Desirable modal characteristics will be determined from literature research and from comments received on the survey forms. Then the corresponding characteristics of two possible University owned mass transit systems and of the one presently operated by the Tucson Transit Corporation will be discussed. Finally, one of these proposals will be selected through the use of a decision model which evaluates the relative merits of each system.

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[3]The service was later improved in September 1972, to include a semi-hourly schedule and evening service.

The findings and conclusions of the study will be summarized in the last chapter. In addition, areas of useful research will be suggested.

CHAPTER II

SURVEY TECHNIQUE

In order to determine the travel patterns of the Christopher City students, the mail survey method of data collection was used. In this chapter, the mail survey technique is first reviewed in terms of general design considerations and then with regard to the specific design of the form utilized to gather the student travel information.

General Survey Design Considerations

The type of survey chosen for data collection was the "mail" survey. Quotations are used in its description because the delivery and return mechanism did not involve passage of the forms through any postal station. However, the principle of its design was the same and the reply procedure did involve active returning effort by the respondents.

Choice of Survey Technique

The mail survey was selected because it was felt to present the most feasible method of obtaining the information necessary to fulfill the aforementioned objectives of the study. Erdos (1970) and Simon (1967) were the chief sources of information reviewed concerning the use of a mail survey. Although they discussed many

aspects of this type of survey, a few prominent ones were particularly applicable to the survey done in this thesis. These important characteristics of a mail survey are summarized in the list below. The four primary advantages in using a mail survey were considered relevant to the information required in this thesis.

Advantages

Elimination of interviewer bias

Chance for thoughtful reply

Savings in survey time

Centralized control

Disadvantages

Population source bias

Non-response bias

Structure of difficult questions

Non-addressee response

The first advantage is the elimination of that bias due to the presence of an interviewer. With the use of the mail survey, the absence of an interviewer naturally eliminates the bias associated with him. There is no change in the respondents' answers due to the interviewer's interpretation of the answers. In addition to the lack of an interviewer's direct bias, there is no bias elicited from the participant. If the person being questioned does not like a particular feature of the interviewer (his appearance, race, possible religious background, etc.), a feeling of non-co-operation can result. This could lead to erroneous answers. In the

mail survey technique, since no interviewer is present, the respondents' answers are not affected in this way.

The next advantage listed is allowing the participants time for a thoughtful reply. Although the questions of the survey used in this thesis are not particularly difficult, they do require a considered reply. The mail survey allows the respondent to complete the questionnaire at his convenience. He will have a better attitude toward filling out a mail survey than answering an interviewer's questions. Therefore, the respondents' answers should be more accurate.

The last two advantageous characteristics listed are the savings in survey time for the researcher and the centralized control of information received. If the mailing method is used, the recipients complete the questionnaires themselves. The only survey distribution and collection required by the researcher involves the mailing process. (For the survey of this thesis, the questionnaires were quickly hand-delivered to the individual apartments and collected at one convenient collection station.) The small center of control in a mail survey provides for uniformity in the quality of data gathering. Only with the use of a mass-produced, pre-printed questionnaire is this type of control possible. There are no interviewers to pose questions to respondents with varying degrees of emphasis and implication. With the use of a mass-produced, pre-printed questionnaire, the questions are presented in the identical "tone" to all recipients.

The first two disadvantages listed are two types of bias that can occur in a mail survey. Often, the source of names from which the random recipients are chosen is a telephone book, a subscription list, or an index of catalog users. An inherent bias can be present due to some underlying unification factor such as social or economic status. The common factor can easily bias the indications of the returns because specific answers can sometimes be directly related to that common characteristic among the sampled population. Another bias that can enter into the survey returns is that due to non-response. If the non-respondents are also grouped together by some common characteristic (age, nonusers, nonstudents, etc.) of interest to the researchers, valuable information becomes unavailable to those doing the study.

The next problem listed on page 8 is that of the respondent not being the addressee. Due to the nature of the postal service, first class mail is delivered to the addressee's place of residence--not to the addressee in person. Anyone at that address may open and complete (or discard) the form before that addressed respondent sees it. Thus, the returns may not truly represent the attitudes of the original sample population.

Another distinct disadvantage of the mail survey is the structuring of difficult questions. Very specific or detailed information is needed in some survey studies. The researcher may not be sure that his questions are properly understood by the participants. As a result, the data received can be misleading

since identical answers could be given in response to differently interpreted meanings of the questions.

Although there were disadvantages as well as advantages in using a mail survey, this survey technique was chosen to obtain the necessary data. The disadvantages were particularly applicable to the survey needed in the thesis. Meanwhile, the disadvantages were minimized by the nature of the data needed and through efforts of the researcher.

Questionnaire Format Features

In the construction of a mail survey, there are certain design factors to be considered. The principal aspects consist of the general format of the questionnaire and the construction of the introduction letter and the questions. A brief summary of the important design characteristics is shown on the next page.

Realizing that the first few seconds a recipient glances over a survey form are the most critical ones in the "life" of a questionnaire, the general format must be given key consideration. The survey's form should appear important and its completion easy. An important appearance is attained by using clear printing (black ink preferably) on white paper. The paper should be of standard size and the printing uncrowded. Any use of glossy or brightly colored paper, a multitude of printing colors, or illustrations should be avoided. These techniques make the questionnaire resemble commercial advertisements--"junk mail" (Erdos, 1970, p. 40). The "easy" appearance is best achieved through brevity. The

General Appearance

Objective	Means
Important	Dark Printing Plain Paper
Easy	Few Pages and Questions Simple Answer Indication

Composition

Objective	Means
Introduction Letter	
Obtain Recipients' Cooperation	Brief Relevance of Survey Show Appreciation Personal
Question Sheet	
Keep Recipient's Interest	Logical Order Proper Wording Varied Answering Methods Reader's Opinion

questionnaire should consist of as few pages and questions as possible. A large number of questions can be reduced in appearance by subgrouping some questions as brief explanations of a few main ones. In addition, the method of answering questions should be easy. Clearly marked spaces located near the appropriate questions will indicate an easy answering mechanism.

The accompanying introduction letter is perhaps the most important means of obtaining the reader's cooperation. First, the letter must be brief in accordance with the aforementioned "easy" look. The introduction letter should also explain to the reader the relevance of the survey. Straus and Peterson (1972) state in their analysis of a transit survey taken in Chicago that "survey form length in itself plays only a marginal role in affecting the rate of questionnaire returns. Perhaps far more critical is the relevance of the survey as perceived by the participants." The final conveyance mentioned, the researcher's appreciation, is also important in the letter. While a simple "Thank You" is almost too mechanical, a single sentence or phrase is sufficient to convey the author's gratitude. Finally, it is helpful to add some personal touch to the introduction letter. The researcher's handwritten signature in the closing will give the respondent the feeling of reading a letter written by another person and not just a piece of mass-produced material.

The actual reading of the questions is the last phase of the reader's examination. The questions must be posed in such a

manner as to maintain the participant's interest. The questions should be arranged so their content follows a logical order. Although this order is necessary, the author must be careful not to introduce bias in the answers by composing leading questions. In addition, the questions must be worded properly. Words that might elicit an emotional response should be avoided. The terminology should be simple and straightforward. The method provided for answering the questions should be varied. Checking, short answer or detailed answering are different techniques of filling out a survey form. Besides its use for variation, the detailed explanation device should be used to permit the reader to express himself. It gives him the feeling of more actively participating in the study instead of being shunned.

Preliminary Composition of Survey

With the various design features in mind, the questionnaire in this study was constructed. As many advantageous facets of survey writing as possible were incorporated into its composition. Various factors were weighed to determine the most useful presentation and questioning.

The survey form was reproduced on a two-page form using standard 8-1/2" by 11" paper. No illustrations or fancy lettering were employed. One sheet contained the introduction letter and one the questions. The number and size of paper were based on providing adequate room for the letter and the questions. Due to

budget limitations, the survey forms were reproduced using a mimeograph machine. This resulted in blue printing on white paper. Most of the reproductions were clear and distinct. The printing on some of the sheets was lighter than preferred. In all cases, however, the survey forms were definitely legible.

Introduction Letter

The cover letter introducing the survey included several important factors but was brief and concise. Only five sentences formed the two paragraphs of the letter.

Figure 3 illustrates a reduced-size copy of the letter. The first sentence of the leading paragraph served three purposes. First, it established the author of the survey--the Department of Civil Engineering at the University. It also introduced the subject of the survey. Mention of the "transportation situation" and "at Christopher City" was done immediately to catch the participant's interest. In addition, the inclusion of the fact that a transportation-related University department was conducting the survey indicated the researcher's competence in the particular area of the questionnaire. The next sentence served the all-important function of instituting the relevance and importance of the study to the reader. Transportation service at this complex was a well-discussed subject and reference was clearly made to this topic. The sentence stated the twofold purpose of the survey--establishment of campus travel and the determination of the feasibility of an improved

April 29, 1972

Dear Resident:

The Department of Civil Engineering at the University is conductiong a study of the transportation situation at Christopher City. The purpose of the study is to establish the campus travel characteristics of the residents and to determine the feasibility of and need for an improved transportation system for Christopher City.

There is a list of 7 questions we would like you to answer. We would appreciate it very much if you would answer the questions and return the survey to the housing office at Christopher City when you pay your rent.

Thank you.

Albert G. Letzkus
Graduate Student
Department of Civil Engineering

Figure 3. Introduction Letter

service. This opening paragraph established the author and introduced the pertinent subject matter to the reader.

The next paragraph attempted tc further encourage the participants to complete the survey. The first sentence indicated the ease of the questionnaire by referring to its seven questions. This was not a large number and indicated that the form could be filled out quickly. The ease of the survey was also designated by the instruction for its return in the next sentence. (It was learned that almost all the tenants pay their rent at the office in person. Since this is a very standard procedure, the respondents were asked simply to return the form to the office during their routine trip. The survey forms were distributed at the end of the month near rent payment time to facilitate higher returns.) The second sentence also served to indicate the researcher's gratitude for the participants' help. The indication here plus the last sentence (Thank you) depicted the author's appreciation of their aid in the study.

While the letter was not personalized in respect to its salutation, the signature was personalized. It included the written signature of the authors. Reference was made to the author's graduate student standing instead of to the cooperating professor's title in order to utilize the sympathy for a fellow student to encourage a larger response.

Question Sheet

A total of seven questions was determined to be sufficient to attain the information necessary to achieve the two purposes of the study. All questions pertained to one or both of the goals: determine travel characteristics and determine the feasibility of a mass transit system for this housing development. The instructions and questions were contained on one page. Side margins were perhaps smaller than desired, but still lacked a crowded appearance. The width of these margins was sacrificed essentially to minimize the survey form to one sheet.

At the top of the survey sheet (see Figure 4) a space was provided for personal information. Below the personal data lie two brief paragraphs. These paragraphs were deemed necessary to help overcome one of the inherent disadvantages of a mail survey--structuring difficult questions. This handicap of self-administered questionnaires was felt to be applicable to a survey used in the type of transportation study conducted. Although the questions were not particularly difficult, it was very necessary to distinguish and clarify the type of information desired from the participants.

The first paragraph was a set of instructions identifying the type of trips the researchers were investigating. Three characteristics of the trips were emphasized due to their relevance to the purpose of the study. They included: "your" household--only the information for each exclusive household was desired to

SURVEY SHEET

Name: _____

Address: _____

Date: _____

Instructions: Indicate the answers to the questions as pertaining to your household, based on a typical school day. The information required is for Christopher City to/from University trips only!

Note: definition of "person-trip"
"person-trip" = each University oriented person making a trip
i.e.; 3 University bound people riding in one car = 3 person-trips

1) Number of person-trips/day. ____

2) Departing time from Christopher City for each person-trip. ____ ____ ____ ____

3) Total time (travel + parking + walking) allotted for trip to campus. ____

4) Departing time from campus for each return person-trip. ____ ____ ____ ____

5) Total time (walking + unpark + travel) allotted for return trip to Christopher City. ____

6) What mode of transportation is used for each trip.

a) your car/motorcycle ____ Number of vehicles ____
average number of riders/trip ____
park at University yes____ no____

b) car pool ____ describe arrangement_____
_____

c) hitchhike ____ number of hitchhikers ____

d) bicycle ____ number of bicyclists ____

e) present bus system ____ number of riders ____

7) Would you patronize an improved bus system (assuming convenient and inexpensive).

yes ____
explain _____
no ____

Figure 4. Preliminary Question Sheet

establish distinct data points; typical school day--only the average characteristics were desired as a day-by-day tabulation would have been numerically prohibitive for data compilation and too time consuming for the recipient to accurately recall (the word "school" is included to emphasize the originating purpose of the trip); and between Christopher City and the campus--these were the particular trips involved in the transportation problem and susceptible to a mass transit solution.

Throughout the questions, the expression "person-trip" was used to insure consistent reference to this type of travel versus, possibly, auto trips per day. The second paragraph explained this term as each person making a trip. This expression was used instead of just "trip" to keep the answers consistent. It eliminated the possibility of a recipient thinking a car trip with two passengers was only one trip. The information regarding trips made by each person was desired because it was necessary to determine the required capacities of a mass transit system.

The set of seven questions followed the introductory explanations. The questions were arranged in a logical order to keep the respondent's thoughts moving in a continuous, uninterrupted manner. Question 1 served the function of determining the total number of person-trips. The answers gave an indication of the volume of trips made each day and the capacity requirements of any transportation service. Questions 2 and 4 then, logically, asked first the trip starting time from Christopher City and next the

starting time for the return trips from the campus. As a check to the understanding of the participants, the number of times indicated for questions 2 and 4 must have been equal to each other and to the answer designated to the first question. The answers to questions 2 and 4 established the daily time distribution of the travel patterns. Following each of these questions were supplementary ones (numbers 3 and 5) to determine the total travel time for each directional phase of the round trip. These questions determined any difference in the to/from time (due to parking locations, varying traffic congestion, etc.) and indicated the maximum feasible travel time for mass transit operations. Note the natural travel time increments explained in parenthesis for each question to keep the participants thinking in an orderly fashion. All of these facets of the travel time were important factors and must have been included in the "total" time.

The last two questions were used to provide additional information for the survey. Question 6 necessarily established the various modes used for trip-making. For this question, the six possible choices were presented to the respondent for selection. Because it is known that different members of the households often use separate (different) vehicles, explanatory notes were added to the right side of each mode. Specific information was desired for each trip and was described in these notes. The descriptive note technique was used for the question to prevent the need of a large number of questions. It also added clarity and

consistency to the answers given. Question 7 served the function of acquiring the Christopher City residents' attitudes toward the bus transit system. Although it was not infallible in predicting the true patronage possible, this data was necessary to vindicate any form of mass transit proposed. It did establish a minimum usage and an optimum goal for possible ridership attraction. A secondary reason for this end question was to materialize the existing attributes and/or suggestions that may surface while the respondent was answering the questionnaire. Originally, the explanation space was intended to supplement a "no" answer to identify the causes of adverse attitudes toward bus riding. However, the resulting location of the explanatory space (between the "yes" and "no" blanks) was not felt to be unhelpful as it permitted a more general clarification of any attitudes a participant may have.

Pilot Study

As previously noted, the researcher was concerned with the proper interpretation and understanding of the questions by the respondents. To test the clarity of the questions used in the survey, a pilot study was undertaken. Its purpose was to determine any misleading or confusing wording in the questions. As a supplementary measure, selected participants were interviewed by the authors to assess the phrasing of the questionnaire.

A graduate class in a Transportation Planning course was selected for the "dry-run" test of the questionnaire. Excluding

the author, the sample size included twenty-seven participants. The students of the class used in the trial survey lived throughout Tucson; they were not residents of Christopher City (with one exception). However, the purpose of this pre-test was to determine areas of confusion in the wording of the questions--not to obtain factual travel data. The sampled students did live off campus and commuted to school. Therefore, they represented travel habits or patterns as did the Christopher City residents. The tested students were instructed simply to substitute their own dwelling for "Christopher City" designations.

From the answers on the pilot questionnaires, a list of "errors" was tabulated. Essentially these misinterpretations centered about three questions as shown in Figure 5. Other, unrelated mistakes were also made but were not included in the analysis. From their nature, they obviously indicated a failure on behalf of the student to listen to instructions and the results were ignored by the researcher. From the analyzed errors and the subsequent interviews, the areas of misunderstanding were uncovered and are explained in the succeeding paragraphs.

Two unclear general points of the survey form involved whether "person-trips" referred to round trips or to one-way trips, and whether the student trips varied with the particular school day. Students immediately asked if "person-trips" in question 1 meant one-way or round trips. Apparently, the leg of the round trip designated in questions 2 and 4 presented no difficulty.

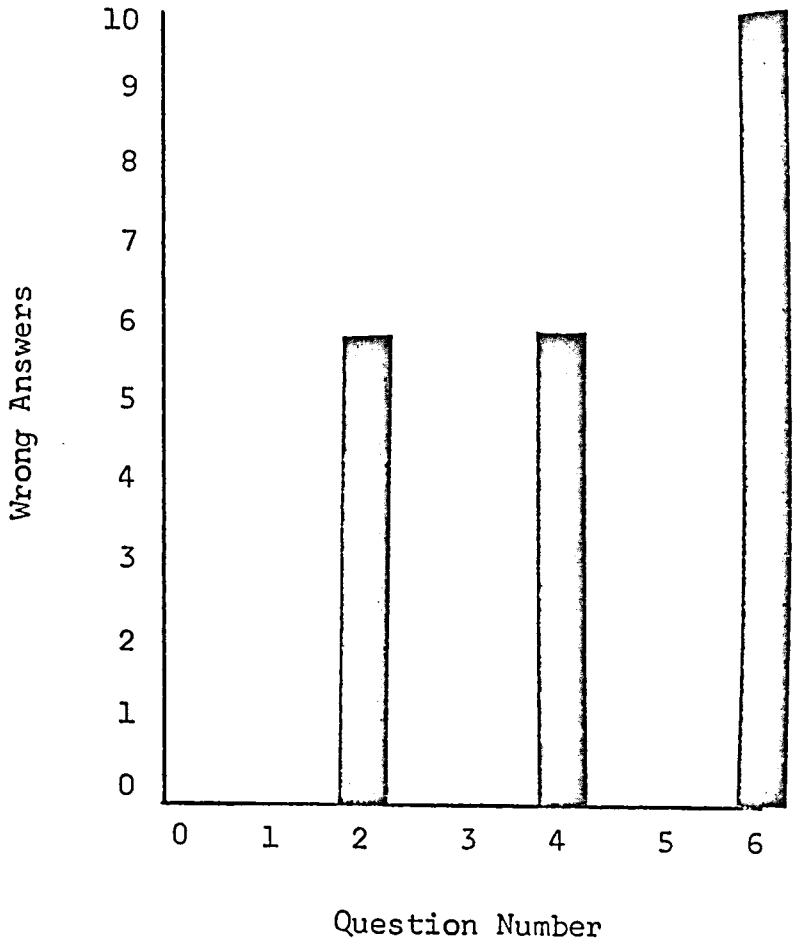

Figure 5. Pilot Study Wrong Answers

Some respondents felt it difficult to approximate an average school day travel pattern because of Tuesday-Thursday classes occurring at different times than the Monday-Wednesday-Friday classes.

The same type of error occurred for both questions 2 and 4 (six cases each). This involved a discrepancy between the number of starting times for each leg with the total number of trips/day answered in question 1. Some of this error was due to an inconsistency in the students' thinking and other error was due to the occurrence of multiple person-trips starting together at the same time.

The only other question in which error occurred was in question number 6. In ten of the twenty-seven forms, the respondents failed to complete the right hand explanatory notes. This was done essentially because the students just did not notice these extra specifications. The participants were simply not aware of them. Some discussion was also raised on choices (a) and (d) of question 6. Did the "riders" referred to in the former choice mean any rider or just University-oriented riders? In part (d), discrepancies between the number of bicyclists and the number of starting times (questions 2 and 4) led to the discovery that participants were including any cyclists in their company regardless of their household origin.

Final Survey Technique

As a result of the information gained from the pilot study, various changes were made in the survey form. The questionnaire,

with the inclusion of these improvements, is shown in its final form in Figure 6.

The confusion about "person-trips" previously described was eliminated by stating the words "round trips" in parenthesis at the end of question 1. The appropriate one-way leg designation of the round trip was felt to be adequate in questions 2 and 4 and warranted no changes. An attempt was made to make the number of completed blanks for these questions consistent with the answer of number 1. A note to this effect was added at the end of both questions 2 and 4. To emphasize to the potential recipient that he should base his travel patterns on an average day, the phrase "typical school day" in the instructions paragraph was underlined differently.

It was considered that the best method to insure that the receivers of the survey would complete the right side of question 6 was simply to instruct them to do so. As shown in the figure, the instructions "FILL OUT BOTH SIDES" were added in capital letters to the end of the question. To further clarify this additional statement, a set of dashed lines was constructed between the choices. These lines better separate the choices and help indicate the entirety of the question. To alleviate the problems with the explanatory notes of (a) and (d), two minor adjustments were made. The underlining of "Christopher City" to/from University" in the instructions was altered and "your household" was added in (d) to emphasize the origin of the tripmaker concerned.

SURVEY SHEET

Name: _____

Address: _____ } OPTIONAL

Date: _____

Instructions: Indicate the answers to the questions as pertaining to your household, based on a typical school day. The information required is for Christopher City to/from University trips only!

Note: definition of "person-trip"
"person-trip" = each University oriented person making a trip
i.e.; 3 University bound people riding in one car = 3 person-trips

1) Number of person-trips/day (round trips). ____

2) Departing time(s) from Christopher City for each person-trip.
(Fill in number of blanks here, equal to answer of question 1) ____ ____ ____ ____

3) Total time (travel + parking + walking) allotted to trip to campus. ____

4) Departing time(s) from campus for each return person-trip.
(Fill in number of blanks here, equal to answer of question 1) ____ ____ ____ ____

5) Total time (walking + unpark + travel) allotted for return trip to Christopher City. ____

6) What mode of transportation is used for each trip. (FILL OUT BOTH SIDES)

a) your car/motorcycle ____ number of vehicles ____
average number of riders/trip ____
park at University yes ___ no ___

b) car pool ____ describe arrangement _____

c) hitchhike ____ number of hitchhikers ____

d) bicycle ____ number of bicyclists (your household) ___

e) present bus system ____ number of riders ____

7) Would you patronize an improved bus system (assuming convenient and inexpensive).
yes ____

no ____ explain _____

Figure 6. Final Question Sheet

In question 7, the "explain" space was lowered so as to associate the explanation with a "no" answer. The response to this answer was the one of chief interest since mass transit patronage might be increased if steps could be taken to remedy the reasons behind the disfavor of it. One last change made in the survey form consisted of the addition of the "OPTIONAL" to the personal data section. It was felt that the maintenance of the residents' anonymity was a beneficial method in increasing the return rate.

CHAPTER III

DATA ANALYSIS

Questionnaires were delivered to all 440 of the apartments in Christopher City. A complete, 100 percent contact was feasible due to the small number of households located in a confined area. By contacting the entire study population, no selection list bias was introduced into the resultant data. All members of the study group were reached regardless of economic, racial, or social status.

Distribution and Collection

Earlier in the thesis, it was noted that the type of survey conducted differed slightly from a true mail survey. The difference lies in the method of distribution and collection of the survey forms. In mail surveys, the forms are transmitted each way through use of the postal system. However, for this study, the questionnaires were hand-delivered by research personnel due to budget limitations. Each survey was folded and deposited in the apartments' mailboxes. The high housing density of this complex facilitated this delivery system. The actual delivery required a total of only six man-hours of work.

As the distribution method did not involve the postal system, neither did the data collection. The residents were

instructed in the introductory letter to return the completed forms to the housing office. It was suggested this be done when rent payments were made as not to inconvenience them with a special trip. A properly designated box was placed in the office and the secretaries willingly agreed to indicate its location to the residents. Approximately one trip per week was made by this author to collect the returned forms. Collection was carried out for about four weeks, although the vast majority of returns arrived during the first two weeks.

Usable Returns

Of the 440 questionnaires distributed, 111 were returned. While the return rate (25.2 percent) was less than desired, it was still considered a good response. One significant factor affecting the return was a problem with the distribution method. As previously noted, the surveys were deposited in the respective mailboxes. Unknown to the researcher, there is a federal law prohibiting the use of mailboxes for non-postal service purposes. Thus, the local mailman proceeded to remove many of the forms upon their discovery. A very rough estimate of the forms removed placed the number at approximately 100. Thus, the effective response rate could have been closer to one-third.

Although this misunderstanding was unfortunate, its effect was not felt to be detrimental to the usefulness of the study. It should be noted that the forms were distributed early on a Saturday

afternoon. The postman did not service the complex until the following Monday. Furthermore, the postman did deposit the forms on the porches after removing them from the mailboxes. A survey form apparently just thrown on the front porch (by the researchers) would not have appeared very important to the participant, but the form had a better chance of being received and completed than if totally discarded.

Other aspects of the non-response bias did not apply or were not felt to seriously affect the results of the returned surveys. Although all the residents were University students, the results were not affected because the information desired concerned University students only and their trips to and from the campus. The results were not biased in favor of an improved transit system (over use of an auto) due only to transit riders responding because (as will be later discussed) a very high percentage of the participants indicated the present use of an automobile. In addition, an analysis of non-responding interviewees by Robinson and Agisim (1951) showed that non-responders were not of a different type to any significant degree than responders. Thus, it was felt that the response to the survey performed for this thesis gave an adequately accurate representation of the actual travel patterns to and from the University by Christopher City residents.

Due to the necessary editing, four of the 111 forms returned were not used whatsoever in the analysis. In addition, only parts of eleven surveys were used to establish the travel

information. Table 1 below depicts the total number of surveys used in the data tabulation for each question:

Table 1. Surveys Used

Question	Surveys Used
1	107
2	103
3	107
4	96
5	107
6	107
7	107

The data for questions 2 and 4 were taken from fewer surveys for various reasons. In some cases, the departure and arrival times were inconsistent, no specific time was given (just "a.m." or "p.m."), or the corresponding trip was not a Christopher City-University trip. The data for the remaining questions were valid and thus were included for data collection for these questions.

The editing or adjusting of questionnaire answers was held to a minimum. Any significant editing done by the researcher would introduce the very bias into the study that was being avoided by using the mail survey technique. However, in some instances,

some minor editing was performed. One such example involved the participant answering question 1 with "2" and then only listing one time each for questions 2 and 4. If the answer for number 6 indicated two trips, then it was assumed that both riders left and returned at the same time. Another type of answer-adjustment done was for the case involving a dual answer for numbers 2 and/or 4. If the respondent indicated traveling time as "25-30 minutes," the time used was twenty-eight minutes. Similarly, if a departure time was indicated as "3 to 4 p.m.," the time used was 3:30 p.m. As previously noted, if any leg of a round trip was indicated as not being Christopher City to/from University oriented, the data regarding this trip was deleted. Three round trips, for example, involving one unrelated side trip (pick up child at nursery, travel to work from school, etc.) were designated as only two-and-one-half round trips/day. In summary, an answer to any one question that clearly conflicted with other consistent answers was "corrected." It can be seen from the aforementioned examples that the editing done was limited to occasional, obviously wrong answers.

Results

The data received were basically grouped into six classifications. These include the number of round trips per day, the daily trip distributions, the travel times, the modes of travel used, the patronage of potential mass transit, and the written comments made by the respondents.

Round Trips

From the questionnaires returned, the answers for question 1 revealed that there are 157 round trips made per typical school day between Christopher City and the University campus. It was important to note that these were trips made with the final destination being at these two end points. Non-University oriented trips were not included. If the recipient mentioned that any leg of the round trip(s) was for extracurricular purposes, then that part of the trip was deleted from the total value. From Table 1 it is seen that data from 107 households were used to determine the number of round trips. Since this represented a sample of 440 apartments, the figure reached was increased by a factor of 4.11 to predict the true value of trips made by the entire complex. As a result, it was determined that 647 round trips/typical school day were made between Christopher City and the University campus.

Daily Trip Distribution

The second type of data involved the daily trip distributions of the round trips made. The departing times (of each leg of the round trip) are grouped together by the nearest quarter hour. The graph in Figure 7 depicts the departure time patterns for trips leaving Christopher City. The amount of trips for each quarter hour is given in percentage of the total one-way trips made (equal to the total predicted round trips for the entire complex). Trips were started as early as 6:30 a.m. and continued to 7:30 p.m. The heaviest concentration of departure times was in the early

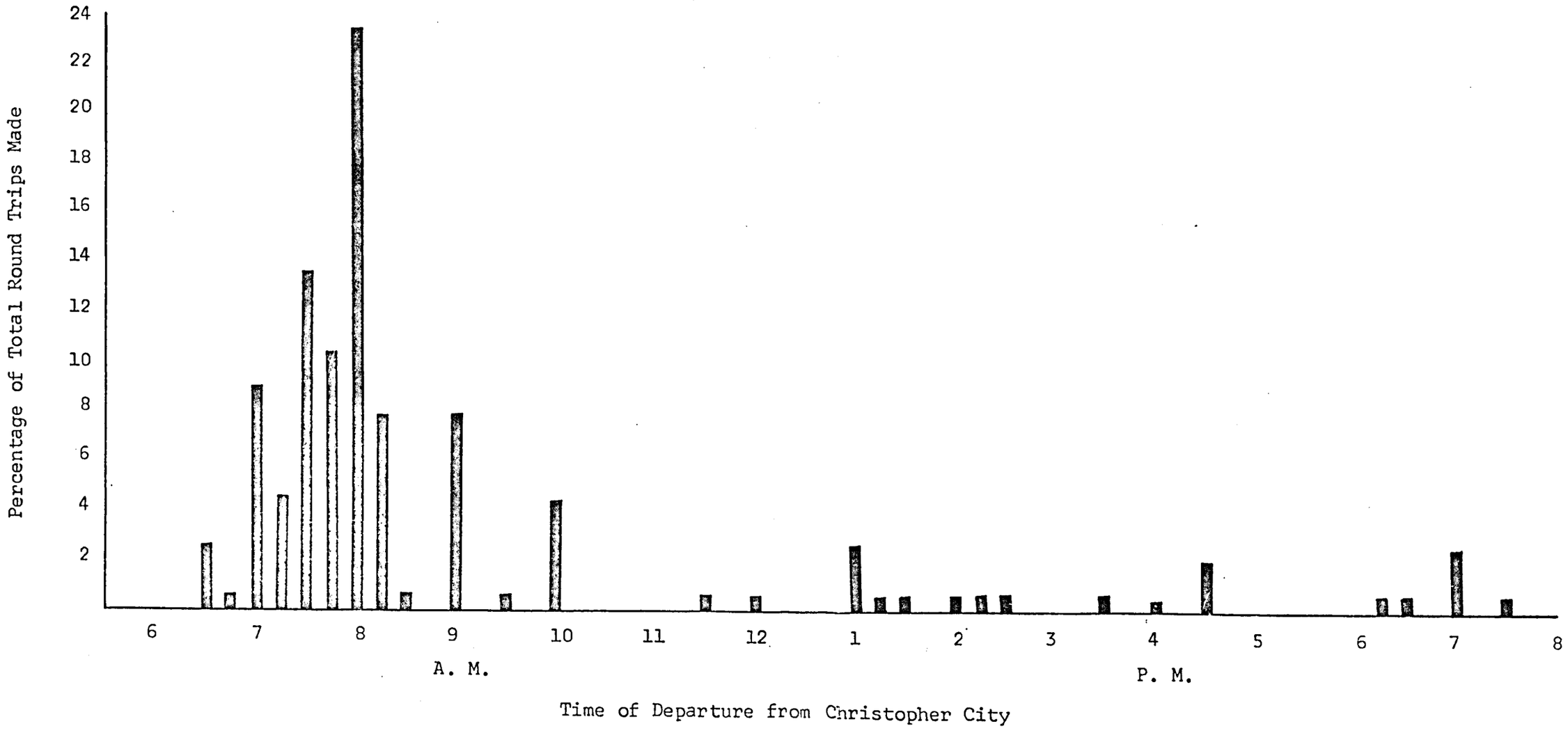

Figure 7. Daily Trip Distribution: Departures from Christopher City

morning and a few times scattered throughout the rest of the day. Over two-thirds of this leg of the round trips was started between 7:00 and 8:15 a.m. This agreed well with an unpublished study done by this author (Letzkus 1971) of a pay parking lot on the campus (see Appendix). It was felt that this study of the arrival-departure time patterns validly represented the daily parking trends at the University as a whole. This study revealed that the greatest, and by far the most significant, arrival rate was attained between 8:00 and 9:00 a.m. with the accumulation peaking during the following hour. Adding about one-half hour for travel time would place a majority of Christopher City commuting residents at parking lots on campus between 7:30 and 8:45 a.m., closely resembling the peak arrival interval established by the parking study.

The distribution of departure times (see Figure 8) leaving the University campus was more evenly spread over the entire day than those for the other leg of the round trips. The departing times from campus started as early as 8:30 a.m. and continued to 11:00 p.m. with some peaking in the late afternoon. This peak departure time was between 4:00 and 5:00 p.m. Just under one-half of all daily departures occurred in this hour-and-a-half interval. While the aforementioned parking study did verify the initial surge of departures from Christopher City found in this thesis, there was no relation found between the peak departure times from the campus.

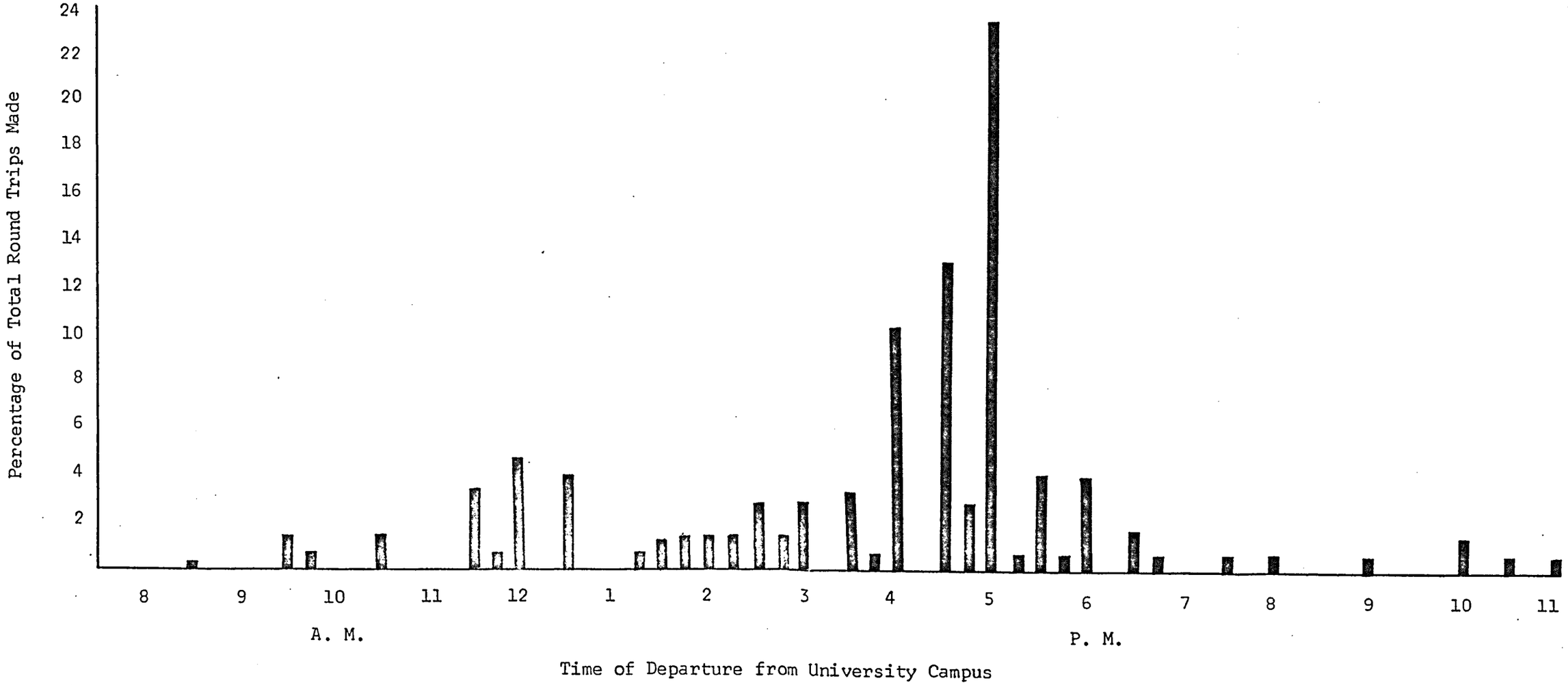

Figure 8. Daily Trip Distribution: Departures from University Campus

Travel Times

The next type of information compiled results from the answers to questions 3 and 5. Regardless of direction of travel, the travel time included that for on-the-road travel plus that in the parking lot (and searching for a space) plus that for campus walking. The average travel time for the trip to the campus was 26.6 minutes. For the return trip from the campus, slightly less time was required--25.6 minutes. The difference in times was not felt to be important. Most respondents indicated the same time required for travel in both directions. It should be noted that these times were those estimated by the commuting residents. It was, however, felt to be relatively accurate as most students become aware of travel time from the repetition of trip-making.

Modes of Travel

There are two sets of information resulting from question 6. The same 107 surveys used to determine the number of round trips was used to determine the modes employed. The first involved the mode of travel used by the residents for commuting to and from the University. Of the six means available, the use of the automobile was the predominant one. Figure 9 depicts the emphasis placed on this mode of travel. Over 70 percent of all trips were made in automobiles. The mode with the second highest patronage was the bicycle with 14.3 percent. The modes of next highest usage were the bus and the motorcycle. While not intended as part

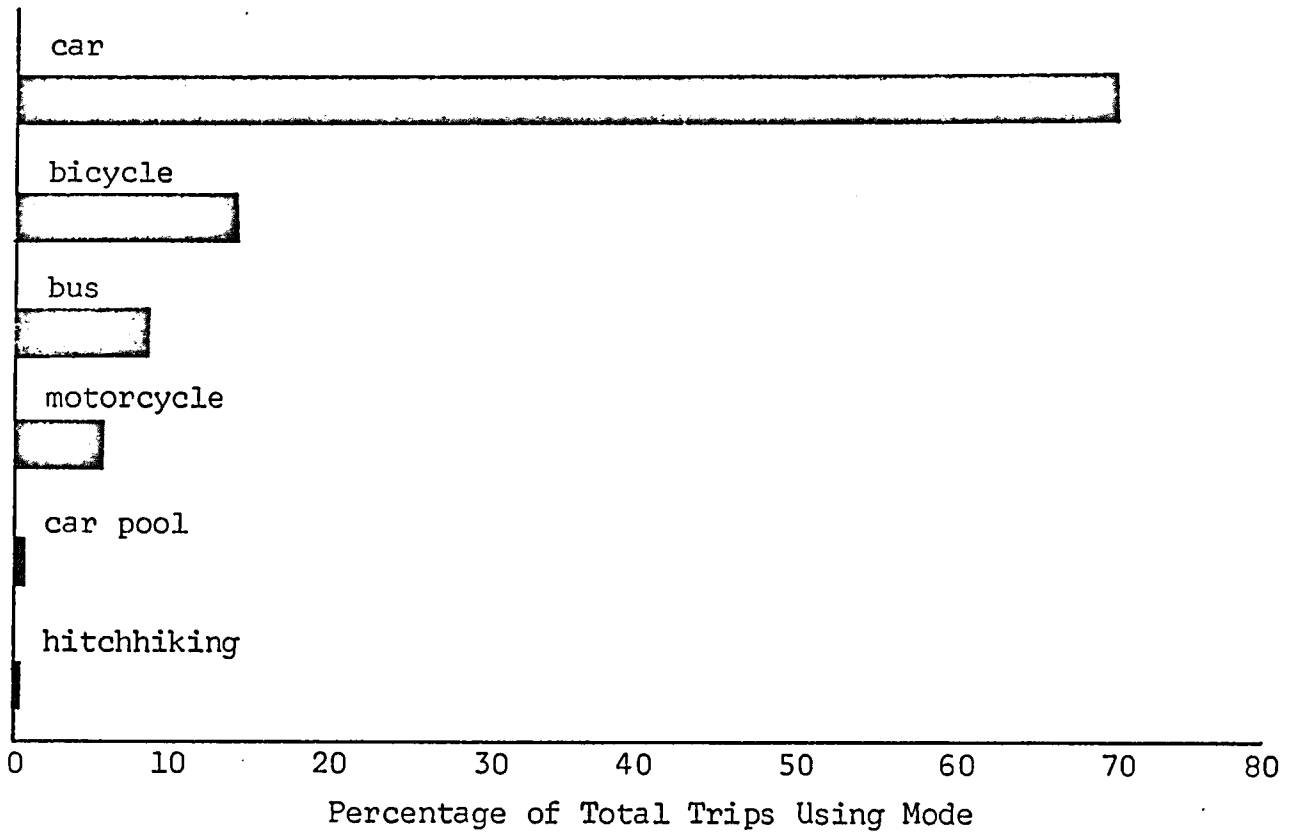

Figure 9. Mode of Travel

of the first question, the respondents practically always indicated which mode included in the first choice was used. These unexpected indications enabled the author to distinguish between motorcycle and auto transit. Only one individual indicated that he made use of a car pool. It involved only one other person. On one survey, the participant indicated that he alternated between three modes of travel--one being hitchhiking.

The second type of information was the number of cars from Christopher City parked on campus. This was data obtainable from the short explanatory subquestion included with the "car/motorcycle" choice. It was determined that there were 376 autos parked on the campus during the course of the day from Christopher City. This value was the sum of all "yes" subanswers, each qualified by the number of trips made to campus in which the car was parked on the campus.

Editing, in general, was done sparingly for the answers of this question. If a respondent marked more than one choice of mode, then equal use was assumed for each. Some residents indicated different modes for Tuesday-Thursday travel than for Monday-Wednesday-Friday travel. Here 40 percent usage was assigned to the former and 60 percent to the latter. Finally, one recipient indicated his own estimation of usage of various modal travel in percentages and his designated values were used. These types of justifiable editing were used for both sets of data compiled from question 6.

Patronage of Potential Mass Transit

The chief purpose for this last question was to determine patronage of an improved bus system. Of the 107 questionnaires used, the residents of sixty-five households indicated "yes"--they would use such a transit system. If the number of trips made by each resident were totaled, 65.1 percent of all person-trips between the housing complex and the campus might be made using a bus. It must be noted, however, that this value assumed that every respondent indicating "yes" would, in fact, use the bus, and that the tripmakers of these households would use the bus for all daily trips. This assumption, of course, would lead to inaccurate demand predictions for proposed alternatives if not factored down. No such reduction method was found in the literature, but this problem of realistic demand prediction and a solution will be presented in the fourth chapter.

Comments

The secondary data obtained from this question were the comments made by the participants. This facet of the question permitted ideas and suggestions to be communicated to the researcher from those affected by the present (and any future) transportation situation at Christopher City. Of the 107 surveys used, sixty-six contained written comments in question 7. As explained in the "Composition of Survey" subsection of Chapter II, reasons why people do not ride the bus were of special interest to the

researcher. These reasons were readily supplied as only three recipients answering "no" failed to explain their answer.

A total of ninety reasons were given by the sixty-six respondents who gave reasons. The most frequent one was convenience. Grouping the references to this quality of transit together, they involved 25 percent of the reasons. Some of the specific comments in this category were: "and returned to Christopher City at convenient times"; "like to see the bus run every half hour"; and "driving myself more convenient to me." The second most common reason (20 percent) was the cost of riding a bus. The respondents referred to specially desired fares and to reducing the fare below the cost of driving their own car. Two other reasons appeared equally under the "cost" factor. These were the preference for riding a bicycle and reference to classes on the medical campus (separate from the main campus), both near 8 percent of the stated reasons. The final significant explanation for transit patronage included references made to non-campus activities after school hours (7 percent). Typical activities were trips to nurseries, to work, etc. Keeping all of these ridership factors and desires in mind, it was possible to propose a more attractive system of transportation for these residents.

CHAPTER IV

SYSTEM REQUIREMENTS

This chapter deals with the requisites of any type of transportation mode to be proposed for use by Christopher City residents to and from the University campus. The literature is reviewed first to determine transit qualities desired by passengers in general. Then, this information is refined by the specific desires of the residents of Christopher City and the practical limits of achievement to set standards for proposed transit alternatives.

Preferences of Riding Public

Various studies have been performed to analyze the desires of the riding public. Efforts were made to determine why a commuter chooses one type of modal system over another--what system characteristics are important and/or attractive to the average rider. All possible factors have been proposed to commuters and as a result of the research, certain salient reasons have been found to be most critical in a rider's choice of travel mode.

A study was done by Golob, Canty, Gustafson, and Vitt (1972) to determine ridership preferences in a transportation system. A self-administered survey was distributed to 1,631 interviewees in a Detroit suburb. To determine modal preferences, the researchers

began with a field of ninety-one various motivating factors that might determine modal choices. This field was then reduced and combined into thirty-two specific factors grouped into the categories of vehicle design, levels of service, and convenience criteria. The data collection involved the use of two types of analysis--a paired comparison survey and a semantic scaling questionnaire. The results of both methods were consistent in their results.

Three specific modal characteristic preferences were significantly more important than those remaining. The people interviewed wanted most to arrive at a planned time, to have a seat, and not have to transfer vehicles. The first reason indicated desire for system dependability while the second two emphasized convenience. Subordinate to these first three in importance came a closely clustered group of nine preferences. These included station shelters, lower fares, and longer service hours. Lower on the scale of desire was a large cluster of eighteen characteristics that were concerned primarily with interior design, aesthetic and social facets of a trip, and personal conveniences. The two least desired choices were the presence on board of special amenities (coffee, newspapers, etc.) and a stylish vehicle exterior.

In summary, this study revealed that riders desired dependability the most. They wish to be inconvenienced as little as possible and were willing even to sacrifice an increased fare level to achieve this convenience. Social and aesthetic interests

were not very important to system users as they appear to assess more the practical aspects of transportation. Personal bonuses such as refreshments, music, etc. were considered frivolous by riders and would only be accepted if no fare increase resulted.

A second study reviewed was that done by Hille and Martin (1967). It consisted of a survey of approximately 800 residents of the Baltimore vicinity to ascertain the modal characteristics desired by the riding public.

In this study, the researchers did not start with a predetermined set of factors. Instead, important travel critera surfaced from the factor analysis done to the respondents' ranking of the importance of forty-four transport characteristic items. Factor analysis was a technique used to reduce a large set of variables to a smaller, more comprehensible set through analysis of linear correlations. The participants were asked to rank the importance of the various modal attributes regarding four trip purposes (work/school, local personal business/shopping, local social, and out-of-town social).

Consistently, the most important attributes emerging, in general (regardless of purpose) were: reliability of achieving destination, convenience and comfort, travel time, and cost. The characteristic of most concern, destination achievement, reflected both arriving safely and at a predetermined scheduled time. For the "convenience" factor, emphasis was placed on the flexibility and ease of departure. The authors' discussion of the value of

the comfort attribute was inconsistent and contradictory. Travel time appeared more important to bus commuters than those using the auto. The authors stated "that bus users placed greater importance on getting to their destinations in the shortest times . . . than did private automobile users."[4] An interesting point discovered in the study was that people generally do not know the true cost of operating an automobile for a given trip. This lack of knowledge, however, did not mean that an upward change in cost would not affect the use of that mode. Other, but less significant, preferences included: independence of control, traffic and congestion, social ("type" of people who typically use the mode), age of vehicle, and diversions.

As previously mentioned, the respondents were asked to rate attributes for four types of trips by purpose. For the purpose of this study, the specific rating of travel mode characteristics for the work/school trip was chosen for its applicability to the subject group of this thesis. The relative ranking of the attributes was practically the same for the work/school trips and for trips in general. The results revealed that the variation in trip purpose was not as important a parameter as originally thought in affecting the preferences of modal characteristics. However, the value of the reliability of destination achievement and travel time were much more important for the work/school trip than for other trips. The importance of reliability (including departure

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[4] Stanley J. Hille and Theodore K. Martin, Highway Research Record, no. 197, 1967, p. 39.

time, prompt arrival, no breakdowns, etc.) reflected the need for being at a job (or class) at a specific time. The travel time seemed to be a deterrent from using the bus for work or school trips. (Although traffic congestion was not considered significant in this particular report, it may very well be much more critical for the situation at The University of Arizona. The combined traffic snarl of cyclists, pedestrians, and cars presents a frustrating ordeal by 8 a.m. for the motorist desperately searching for the elusive vacant [student] parking spaces.)

The third study related to ridership preferences that was reviewed was the one performed by McMillan and Assael (1968). One objective of this nationwide survey of about 2,000 households was to determine public attitudes toward transportation development.

In their report to the Highway Research Board, the authors indicated the preference of riders for the automobile instead of a bus system. The attributes of importance listed in this study reflected this preference. They included: arrival at destination safely, no mechanical breakdowns, no dependence on other people for transportation, no vehicular transfers, weather protection during wait for ride, uncrowded vehicle, and riding comfort. Findings of other studies have included cost and convenience as priority desires. Comfort, safety, and travel times also appeared important but to lesser extents than the other two.

While variance did exist in these reports to the designation of attributes and to their exact relative importance, certain modal

desires did consistently appear. The few most important factors cited in this literature were:

Prompt destination arrival

Safe trip

Travel time

Cost

Convenience

Weather protection

No relative individual importance was to be inferred by the order of the listing.

Desires of Christopher City Residents

Besides determining modal characteristics preferred by the general public, the modal preferences of the Christopher City residents were also investigated. Although ridership preferences revealed in the literature were generally applicable to this survey population, it was necessary to determine any distinct variations due to the specific transportation situation at Christopher City.

Reviewing the discussion in the "Comments" subsection in Chapter III, it was noted that five salient modal choice reasons were given by the participants. These included (in order of most to least important) convenience, cost, commuting to the medical campus, the preference of a bicycle, and extracurricular activities. The "convenience" factor included the specific reasons of the

desire for semi-hourly service, evening service, and the greater convenience of the modes (other than a bus). The "cost" item included specific fare rates and the notion that the bus system was too expensive. The participants' reference to the medical school reflected the fact that this particular school was located on its own distinct campus physically separated from the main University campus. The servicing of the medical campus was, of course, a fundamental criterion of medical students using any particular mode. As stated by the respective respondents, the favoring of a bicycle as transport indicated the desire for the physical exercise inherent in its use. The extracurricular activities included after-school employment, trip to nursery, and personal non-academic errands.

The first two criteria--convenience and cost--were typical of those stated by the general public and will be included in the alternative evaluation process. The medical school reason will not be included as a specific decision factor, but will be explicitly involved in the route taken by any proposed alternative. The route taken, regardless of mode, will pass nearby the medical school and make one stop there in each direction between the main campus and the housing development. The "bike" factor will be deleted from the selection determinants, as the basis of its preference is not homogenous with that of the other transport modes. Finally, the provision for extracurricular activity trips was excluded since this type of trip was not covered by the study

(only direct University to/from Christopher City trips). Thus, as a result of the literature review and the respondents' comments, the following criteria will be used in the alternative evaluation process:

Convenience (scheduling)

Cost

Safety

Travel Time

The relative importance of these criteria will be explained in Chapter V.

Note that the last two were criteria derived from the "general riding public" preferences. Although not specifically mentioned by Christopher City residents, these criteria were felt to be significant (perhaps naturally assumed by these residents). The "prompt destination arrival" will not be a factor in itself as it was essentially part of the convenience criterion. The weather consideration was not applicable to The University of Arizona because of its location in southern Arizona. (The major occurrence of influential weather usually occurs only during the rain season of July and August. However, this time of the year occurs concurrently with the University's academic recess with commuting trips at a minimum.)

CHAPTER V

SYSTEM DESIGN

From the preferred system characteristics established in the preceding chapter, a transportation system can be designed to best meet the needs of the Christopher City residents. It is essential to know the important features required of a system in order to assure that the appropriate information concerning the possible alternatives will be presented. In this chapter, the pertinent data of three proposed alternative modes of mass transit are presented. These data are then substituted into a decision model to choose a final transportation mode.

Proposed Alternatives

The transportation system proposals presented in this thesis will be practical and easily implemented. No review is given to very expensive (subway, monorail, etc.) nor to experimental systems (skybus, demand-responsive jitney, etc.). The three alternatives which are proposed for consideration are 1) the GMC full-size bus (model T6H-4523A), 2) station wagon vans, and 3) the present (upgraded) system. The first two differ from the third with the former being University owned and operated systems. The third modal choice is essentially the "zero-change" alternative.

It is also used as a base for comparison with the relative merits of the new system. This alternative is described as "upgraded" because of an increase in service which started in September 1972 (after the survey was performed).

The route to be used for the two new modal systems will be: Fort Lowell Road to Campbell Avenue to University Boulevard. The terminal points will be at the present bus stop location at Christopher City (see Figure 10) and in front of the Student Union at the University. The total round trip distance is twelve miles. The chief reason for the route is to facilitate a short stop at the Medical Campus on Campbell Avenue. All systems, therefore, serve an indicated demand for trips to the medical school (the Tucson Transit Corporation provides service to this school, but on a different route than is used for Christopher City-University trips). The placement of the bus stops facilitate both familiarity and a centralized location.

It is not felt necessary to add additional bus stops at Christopher City. The average walking time to the present location from the housing units is only about four minutes. Additional stops on the main campus could be warranted in the future if the demand existed. However, they should be very limited in number as to minimize the total travel time between the campus and the housing complex.

Question 1 revealed that as many as 421 round trips/day might be made on an improved bus system. However, a resident may

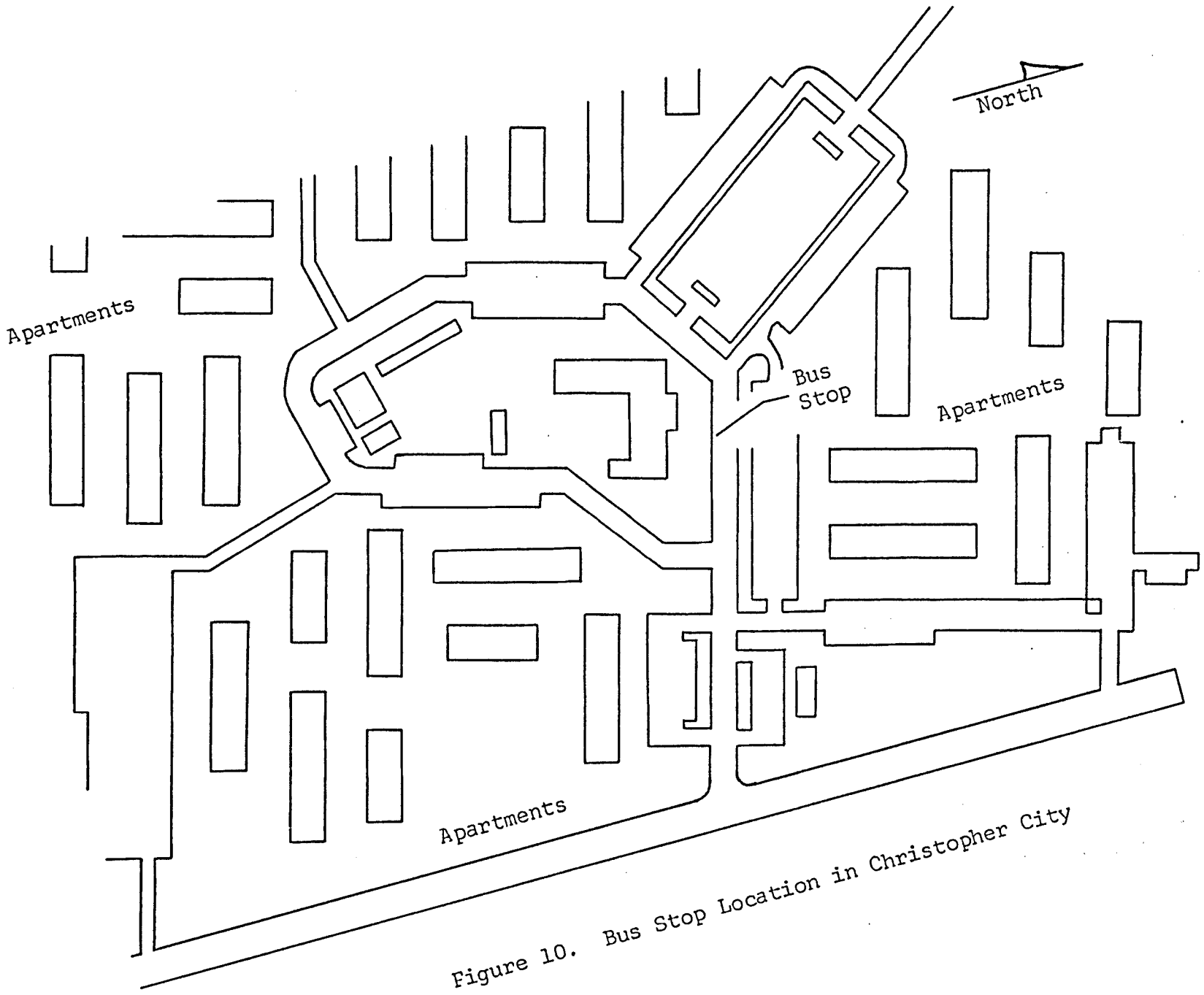

Figure 10. Bus Stop Location in Christopher City

not necessarily use such a system if implemented, although he will indicate so in a questionnaire. There are no techniques available to convert indicated usage to true usage. Therefore, the ridership will be assumed to be 50 percent of the indicated number of person-trips. It results in a daily bus usage of 211 round (person) trips. This somewhat arbitrary value lies between the 65.1 percent ridership indicated and the 8.4 percent usage at the time of the survey. Costs for the student commuter and for the University will be calculated using this ridership percentage. The cost/trip for a resident will be based on the bus fare. The yearly cost for the University is the cost of providing for parking spaces on campus and the expense of operating a transit service for the residents of Christopher City.

GMC Bus

The first proposal for a transit system involves a University-owned service using a full-size bus produced by General Motors Corporation. The particular bus to be used is designated as model T6H-4523A. This is the same model as the ones recently purchased and placed in operation in Tucson by the Tucson Transit Corporation. It is an air-conditioned bus with a V6 diesel fuel engine and has an operating lifetime of fifteen years.

Figure 11 depicts the time distribution of the 211 person-trips to be carried by the various proposed systems. By 8:15 a.m., 151 passengers must be started on route to the University campus.

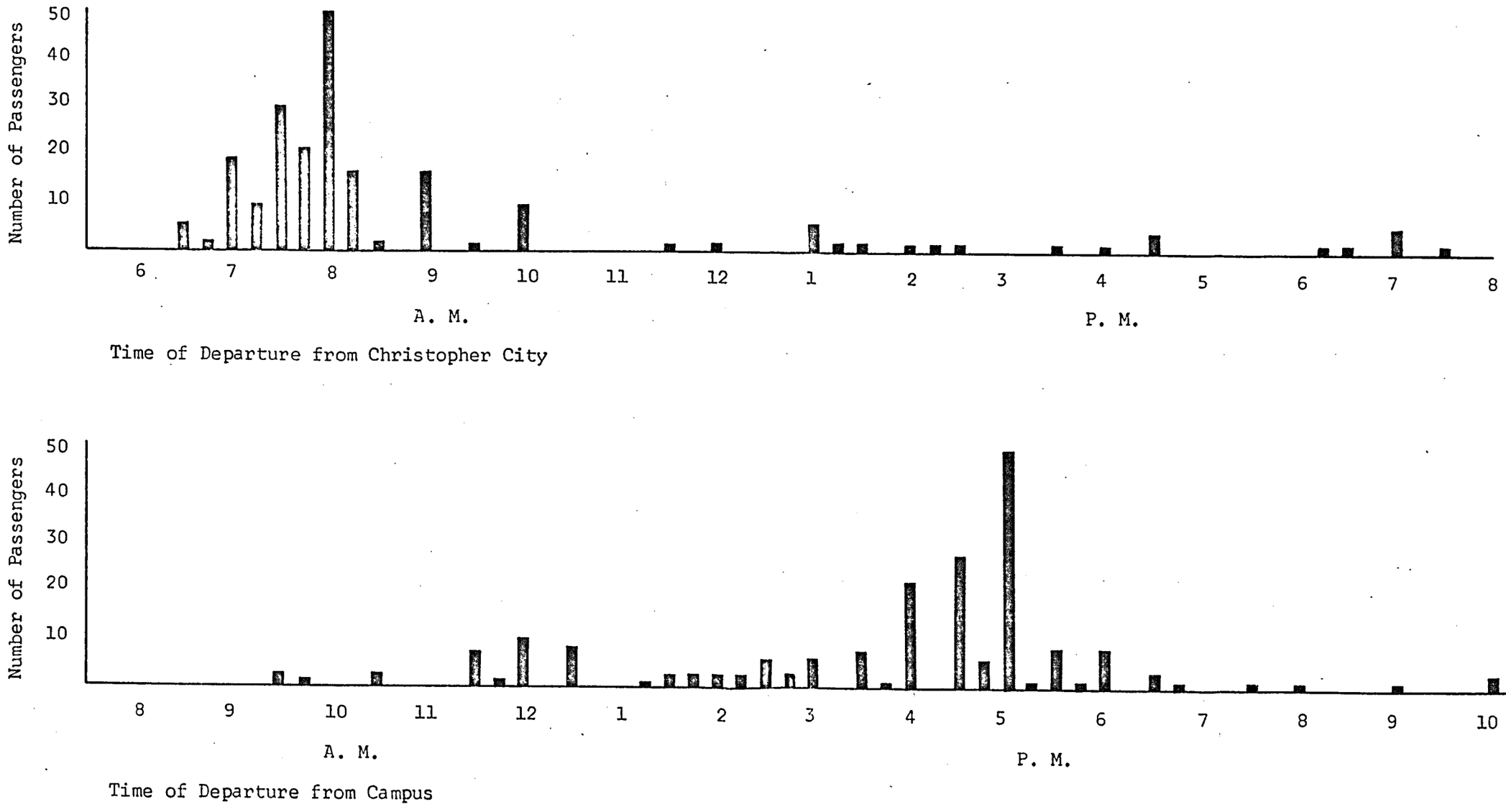

Figure 11. Mass Transit Hourly Capacity Demand

In the evening, from 4:00 to 5:00, 105 passengers must be carried back to Christopher City. These two heavy concentrations determine the rolling stock necessary to facilitate demand. Semi-hourly service (requiring two buses due to travel time) almost meets this demand and would be sufficient. Therefore, this system will consist of two buses, each making one round trip/hour. Operations will run in both directions on the hour and at half past the hour (based on the new class starting times) commencing at 7:10 a.m. and the last departing at 11:10 p.m., Monday through Saturday. This results in a total daily mileage of about 500 miles. In addition, one extra bus will be needed to replace a breakdown and to cycle the buses allowing for periodic maintenance.

The second part of this transit system consists of the parking spaces provided by the University to accommodate cars from Christopher City. Based on the results of questions 2, 4, and 6, there are 2,458 car hours of parking from the housing complex on an average school day. Assuming that the increase in bus ridership (from 8.4 percent to 32.5 percent) is drawn from the present auto trip makers, this new proposed system results in a reduction to 1,620 car hours on campus. If the effective daily availability/usage of parking spaces on campus lots is considered to be twelve hours, this new system requires 135 parking spaces/day.

The seating arrangement on the GMC bus allows for ample leg and shoulder room. The aisles are of adequate width and, in general, there exists no cramped feeling inside the bus. Although

the interior exhibits roominess, the seats may not be comfortable. Because they are made of a thin plastic material, it is possible that the seats would provide a hard ride. The large, tinted windows will provide for exterior viewing with the elimination of the heat and glare from the intense Arizona sun.

The scheduling convenience depends on the frequency of service. The semi-hourly service is considered satisfactory. The departure times are oriented toward delivering the students to campus with time to attend the classes which start on the hour. The terminal stations are convenient both at Christopher City and at the two campuses. Only a few minutes are required to reach the first from any of the households. The bus stop on the main campus is at a very centralized location. The bus stop for the medical campus requires only a short walk to the facilities.

The total travel time required for a trip using this GMC bus system is approximately twenty-four minutes. This includes a four minute walk to/from the Christopher City station to the households and fifteen minutes actual riding time. An additional five minutes is added to account for waiting time as few riders will arrive just as the bus leaves. Because the bus stop on campus is at the Student Union, a center of activity and an average destination on campus, no time is added for walking to/from this bus stop. This center of destination is used to compare the total travel times of all the modal proposals.

This large bus is considered a safe means of transit--far safer than an automobile. The bus is much larger and heavier than a car, providing more inherent safety in multi-vehicle collisions. The passengers are sitting higher above the ground and farther back from the front of the vehicle. Buses, as a rule, travel more slowly than the rest of traffic. Acceleration and deceleration rates are lower than those for automobiles. Commercial vehicles, operated by properly licensed professional drivers, are driven more responsibly than private autos. The result of all these factors is safer transportation for the passengers. In 1970, for example, there occurred nineteen bus-passenger fatalities per million passenger miles. This represents a safe mode when comparison is made to the 210 automobile deaths per million passenger miles during the same year. Thus, this large GMC bus is considered a safe mode of transport.

The last, but no less important, factor of this mode is the cost burden for the various interests involved. Essentially, that group having the strongest influence in the acceptance of a system is the University itself. Although the cost to the riders is important, the cost to the University will chiefly decide the acceptability (from a cost standpoint) of a system in the final analysis. From past (and present) experience, a transit system has little known chance of supporting itself from its revenues only. Thus, it is felt that the fare should be based on the riders' ability to pay rather than as an attempt to make the system self-supporting.

A round trip fare of twenty-five cents is deemed acceptable based on comments from the survey and discussions with Christopher City residents. This fare is one-half that of the existing expense to ride the present Tucson Transit Corporation's system.

The University's cost will be based on an equivalent annual cost of providing the transit service and the necessary campus parking spaces for the non-users. As stated earlier, three GMC buses will be needed to operate 500 vehicle miles per average school day. The resulting annual cost for this part of the system is $49,699. This represents the expense incurred from amortized capital costs, vehicle operating costs, drivers' salaries,[5] and less revenue. No maintenance facility, administration or insurance costs are included. It is felt these will be the same for the two University-owned systems and do not enter into the decision process for the comparison between these systems.

However, the deletion of these costs will make the cost estimate for the two University-owned systems conservative when compared to the system operated by the Tucson Transit Corporation. The consequence of this cost estimation difference will be discussed in Chapter V.

The second part of the cost arises from the need to provide the 135 parking spaces/day for the remaining auto users. To establish an annual cost/space, many assumptions and approximations

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[5] Salary is based on a reduced University student worker rate of $2.00/hour.

are necessary. However, the final result is considered adequately accurate for the level of the modal system comparison in this thesis. Basically, the cost of building recently paved lots is determined and then divided by the total number of provided parking spaces. In addition to this figure, an estimate by the author with help from consulting engineers of annual maintenance costs, is added to give a final annual cost/parking space.[6] As a result of these calculations, a value of $134.26/space/year is reached. Thus, the annual cost of providing parking spaces for the non-users of this transit system is $18,125. The total net cost, then, for a University-owned, GMC shuttle service is $67,824 per year.

Station Wagon Van

The second mass transportation alternative, also University owned and operated, is one using station wagon vans as the vehicles of transport. This type of passenger van includes the models "Sportsvan" sold by Chevrolet, the "Sportsman Wagon" produced by the Chrysler Corporation, and the "Falcon Club Coach Wagon" manufactured by the Ford Motor Company. No attempt is made to present any one of these types of vehicles individually. Instead, just the type of vehicle will be proposed.

The overall physical characteristics and dimensions of these vans are similar to that of an automobile station wagon, with

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[6]William Hibbs, Consultant Engineer, Blanton & Company, Tucson, Arizona; Clarence Meines, Maintenance Foreman, City of Tucson, Tucson, Arizona; Wayne Fasel, Industrial Consultant, Tucson Gas & Electric Company, Tucson, Arizona.

the exception of height. In this category, the van is somewhat higher than an automobile station wagon. The passenger capacity for a van is ten for comparison purposes. The important extras necessary for this vehicle are air conditioning and an automatic transmission. The V8 gasoline engine in the vans operates on regular fuel. No particular economic lifespans are available for this type of vehicle. However, since they closely resemble the typical car in cost and operation, a capital life of five years is considered a good approximation.

Again, the peak hours' demands determine the necessary vehicles. However, one advantage of this "minibus" system is its flexibility during off-peak periods. It would be wasteful to operate a heavy schedule resulting in many empty vehicles during parts of the day. Therefore, a schedule will be designed by average demands, supplemented by extra vehicles during the "rush hours." Service will consist of a thrice hourly schedule with vehicles departing on the hour, twenty minutes, and forty minutes past the hour. One bus will depart from Christopher City and from the University campus at each of these times. Three runs, hourly, instead of two, are chosen due to the dispersed distribution of return trips from the University. The daily service would begin at 7:00 a.m. and end with the last departure at 11:00 p.m., Monday-Saturday. To handle the early morning demand on Mondays through Fridays, two additional buses will leave simultaneously with the regularly scheduled bus for the first five departure times. These

same additional four buses (two extra, each way) will then again be used for the four runs between 4:00 and 5:00 p.m. Because the extra vehicles operate only about three hours per day and can be used to substitute for the regular service in case of a breakdown, one extra bus (for a total of seven vehicles) will be purchased for special standby service. If, during any one day, two buses are down simultaneously, then only the peak two hours will suffer lower service for a day until repairs are made. All vehicles will be used in rotation to evenly distribute the total route mileage among them. This total daily mileage is approximately 1,135 miles on each day, Monday-Friday for the system described (Saturday is only 660 miles).

The seating arrangement consists of two seats behind the driver, each carrying three passengers, followed by a larger third seat carrying four. Various publications list a capacity of twelve. The extra two arise from including the driver and an additional single-person seat separated laterally from the driver by a large mechanical hub. This one extra rider is excluded due to the necessity of self-opening the door and a difficult entrance. While the seats are comfortably padded, the unmistakable feeling of crowdedness is present with a full passenger load. Each of the three seats essentially carries one too many people. In addition, the closed-in feeling is enhanced by the lower head room and limited window area. To provide easy entrance/exit, the large double door on the right side must be opened. It is felt that the driver

performs this operation, necessitating his leaving the vehicle during the station stops.

Because the service is three times per hour, it is more convenient than the GMC mode. Only the on-the-hour departure will be slightly undesirable as it will deliver the riders more than a half hour early to class. The use of three runs is influenced by the scattered return times in the afternoon and the lower capacity per vehicle. The centralized location of the terminals makes the use of this system also accessible to its riders.

The complete travel time for the van system is twenty-six minutes from house to the StudentUnion. The slight increase in time (compared to the GMC bus service) is due to the longer pick-up time at the medical school. The necessity of the driver leaving and re-entering the vehicle will require about two minutes. The trip time by way of this mode also includes the four minutes' to/from household to/from bus stop, the fifteen minute driving time, and the five minute waiting time.

Unlike the GMC system, the van mode is not considered very safe. Because a van's physical characteristics resemble a car, the van is similarly maneuverable as an auto--more so than a large bus. However, this benefit is negated by those same dimensions making the vehicle more sensitive to the destructive forces of collision impacts. The extra height combined with the shorter wheelbase makes this vehicle susceptible to tip-over in high winds and tight turns. Braking performance is less than desired. Sharp

deceleration results in nose-over and loss of traction in the rear wheels. Skidding of the rear wheels is inherent upon quick stops and results in steering instability. The significance of these poor handling qualities is that, while a driver naturally drives a van as an automobile (similar size, etc.), the vehicle is much less designed to safely handle emergency traffic situations.

The fare for this system will be the same as the other University owned system--twenty-five cents/round trip. Seven vehicles and the 6,335 miles/week represent the sources of capital and operating cost of the van mode. The resultant cost for the transit system of $35,401/year again does not include maintenance shops, administration services, nor insurance. Since the ridership for this mode attracts the same number of automobile users away from their cars, the required number of spaces per day is equal--135. Therefore, the total annual cost of the station wagon van system is $53,526 for the University.

Present (Upgraded) System

The transit service for Christopher City is provided by the public bus line in the city of Tucson. The company operating the system is the Tucson Transit Corporation, but the rolling stock is owned by the City of Tucson. The designation of "upgraded" refers to increased service instituted since the survey was taken last spring (1972). This improvement will be discussed more in detail later.

The vehicles used for this mode are the same GMC buses described in the University owned proposal--model T6H-4523A. The route used between Christopher City and the main campus is by way of Fort Lowell to Blacklidge Drive over to Glenn Street, and finally down Park Avenue. This route (number 1) does not pass by the medical school. In order to travel to/from the medical campus, it is necessary to take "number 11" down Alvernon to Grant Road. Here, a transfer must be made to "number 9" continuing west on Grant Road and then down Campbell Avenue. The stations are as described before at Christopher City, but at the "main gate" on University Boulevard on the west side of the campus.

The reason this system is described as "upgraded" is due to increased service starting early in September of 1972. The daily coverage of service is increased by starting earlier at 5:44 a.m. and providing evening service (until 11:25 p.m.). The hourly service is increased to semi-hourly service until 6:25 p.m. (from the University), Monday through Friday. In addition, Sunday scheduling is provided, being the same as Saturday's hourly service.

The increase in service to semi-hourly runs makes this system much more convenient for Christopher City residents. The twice hourly capacity of these vehicles was previously stated as capable of meeting the demand. The addition of evening service simulates that of the University owned alternative. The arrival times of the buses at the main gate (from Christopher City) are approximately at eight and thirty-eight minutes past the hour.

Even with the time required to walk to the center of campus, these times allow the riders to reach their classes on time. The first time, however, does, in fact, deliver the student too early (over three-quarters of an hour). As for comfort, the two alternatives are equal (same equipment results in same ridership qualities). However, due to the occasional use of the antiquated buses by Tucson Transit Corporation, sometimes the comfort is lowered. Essentially, the improvements make this publicly owned system comparably convenient (and comfortable) to the University owned counterpart.

The total time to travel using the existing system is forty-two minutes. This is much longer than the twenty-five and twenty-six minute times of the first two proposals. The significant increase lies in the public nature of this system and the terminal at the main campus. Because the system operates to transport the citizens of Tucson, it must make periodic stops (particularly inbound) to pick up passengers between Christopher City and the campus. This, of course, results in a longer road time. Nine of the seventeen minutes of total time increase comes from this increase in road time. The remaining eight minutes arise from the bus station at campus being at the main gate. This location is not centralized relative to campus activity and results in a long walking time after the bus ride.

The safety of this transportation system is equal to that of the University owned proposal due to the same vehicles being

used. The operation of the public transit's vehicles by professional drivers does not increase the safety of the system beyond that of the University owned service. It is felt that the traffic conditions and the traffic control devices existing along the route effectively neutralize the drivers' effect on the safety of the respective transit systems.

The cost of this present system to the University consists of two parts. The first, the annual parking space provision, is the same as the other two modes: $18,125/year. The same 135 spaces/day are needed regardless of the system chosen. The second source of this present system will come from a direct fare subsidy from the University. The University will not operate any vehicles of its own; it will have no direct modal system for Christopher City-University transportation. Instead, the University will assume the burden of one-half the cost of a trip on this public system. Thus, the student will pay twenty-five cents/round trip. This can be accomplished by the University buying tokens from the Tucson Transit Corporation and then selling them to the students at half price. Convenient exchange counters can be provided for the residents at the housing office at the housing complex and at the information desk in the Student Union. Tokens should not be sold on the buses themselves as not to increase the traveling time; full price cash fares would be permitted. To pay for this system, the cost to the University would be $9,416/year.[7] Thus, the total

[7]Based on thirty-four school weeks/year, 5.25 days/week, 211 round trips/day, twenty-five cents/round trip subsidy.

annual cost to the University for the present (upgraded) system is $18,125 (parking spaces) and $9,416 (fare subsidy) for a total of $27,541.

Selection of Modal System

Now that the various aspects of the three proposed systems are known, one must be selected. It will be chosen on the basis of its fulfillment of the desires of the residents of Christopher City and its financial burden on the University.

Decision Model

In order to choose the most feasible system, the four areas of critical importance are weighed for each alternative relative to the others. The pertinent factors are: 1) convenience (and comfort); 2) travel time (total); 3) safety; and 4) cost (to the University). While all of these items are probably of equal consideration to the student users of the system, the most critical factor to the University is cost. The University would most likely implement that system that is the least expensive. While student pressure could influence the administration's decision, there is no way to measure the effect of this potential pressure. Since the cost estimates are only approximate, this factor will only be given twice the weighting value of the other factors. These three factors will each influence the decision with a value of unity.

The selection technique used is a simple mixed-rating comparison. It compares systems relative to some base system. This

method utilizes selection factors presented on interval scales and on ratio scales. One form of interval scaling involves formulating a simple acceptability scale, i.e., one to five. "One" indicates a high degree of favorability and "five" a low one. This type of scaling is used to compare qualitative factors such as convenience and safety. To evaluate the quantifiable aspects of the system, the travel time and the cost, a direct ratio of these values is determined. A ratio less than one indicates the preference for that system used in the numerator. The mixed-rating technique now simply determines an overall multiplication ratio of both the interval and the ratio factors. The relative importance of the factors is present in the form of raising that particular ratio to the power equal to the relative weight of the factor. The relationship below demonstrates the application of the mixed-rating comparison to the study at hand.

$$\frac{\text{new mode}}{\text{present mode}} = \left\{\frac{\text{convenience}_{new}}{\text{convenience}_{pres.}}\right\}^{1} \times \left\{\frac{\text{travel time}_{new}}{\text{travel time}_{pres.}}\right\}^{1}$$

$$\times \left\{\frac{\text{safety}_{new}}{\text{safety}_{pres.}}\right\}^{1} \times \left\{\frac{\text{cost}_{new}}{\text{cost}_{pres.}}\right\}^{2}$$

Each of the two new (University owned) systems will be compared to the existing public transit service.

Selected Mode

The factors of the three modal alternatives are summarized in Table 2. Note that the convenience rating for the first two systems are equal. This is essentially due to the spaciousness of the former offsetting its less comfortable seats compared to the latter system. Both are equally convenient regarding Christopher City bus stop location, but are more favorable than the present system in their campus stop location and its direct, non-transfer service to the medical school. As previously stated, the safety of the systems using the same large GMC bus is equivalent and much safer than the van-operated mode. As a result of the mixed-rating comparison equation (see equation above), the presently operating public system is more feasible than either of the University owned systems. The comparison between the University owned and the present Tucson Transit Corporation owned GMC bus systems results in a ratio of 2.4:1 favoring the latter service. When compared to the van bus system, the present system again is more desirable (3.1:1). Regardless of the University owned system, the presently operating system is preferred. Comparing the two University owned systems, the GMC bus mode is preferred to the van mode, but not to a great extent.

Although the ratio values indicating the selection of the present system instead of the University owned systems are not large, these ratios represent a conservative choice of the present system. Recalling the discussion in Chapter V, the cost of

Table 2. Decision Factors of Alternative Modes

Alternative	Convenience	Travel Time (minutes)	Safety	Annual Cost (dollars)
University Owned GMC Bus	2	25	1	67,824
University Owned Station Wagon Van	2	26	2	53,526
Tucson Transit Corporation GMC Bus	3	42	1	27,541

operating the University owned systems was underestimated with the deletion of maintenance facility, administration, and insurance costs. Thus, even with the costs minimized for the University owned systems, the decision still favors the presently operated system.

Some reservations must be kept in mind when viewing the results of this technique. First, the resulting output (answer) is limited by the value of the input. The information from the surveys is based on only a sample of 25.2 percent of the residents living in Christopher City. While it is felt that this is an adequate size, not all residents were contacted due to the postal service problem. Inherent cost estimations are included in the University expense burdens. In addition, many cost influences are assumed equal for all alternatives, which may not be the exact case. Second, the selection technique used involves the author's judgment in some aspects of the scaling. The interval rating of the safety and convenience factors is somewhat arbitrary and was left to the discretion of the author. While the scaling is based on the important considerations, different authors arrive at different relativity ratios.

Sensitivity Analysis

Because the use of the decision model did require subjective judgment by the author, it is important to determine the effect of this judgment on the resulting choice of mode. Sensitivity

Analysis is a method used to determine the effect of the variability of the subjective inputs on the resulting decision. Basically, the values of the variables are maximized and minimized to find the upper and lower bounds of the decision. In an ideal model, the choice is made scientifically with no subjectivity involved. For a less perfect model, if any variable values must be chosen somewhat arbitrarily, then the effect of the flexibility of these values should be minimized to insure a more reliable decision.

For the decision model used in this study, a mixed-rating comparison, the variable values that were subjectively chosen were the scaling values of the qualitative criteria and the weighting values of the criteria ratios. The quantitative values of travel time (in number of minutes) and cost (in dollars) were estimated objectively and were not subject to arbitrary choices.

First, the effect of varying the scaling values of the two qualitative criteria, convenience and safety, were investigated (see Table 3). For the decision used to select the present transit system, convenience ratings of 2 were given to the two University owned systems and a less favorable rating of 3 was given to the present system. As a result, the present system was selected over the University owned GMC system by a ratio of 2.4 and over the University owned station wagon van system by a ratio of 3.1. If the convenience for the present system is maximized (scaling value of 1) and minimized for the new alternatives (scaling value of 5),

Table 3. Sensitivity Analysis: Effect of Scaling

	New GMC System/Present System		New Van System/Present System	
Extreme Variation	Convenience Ratio	Decision Ratio	Convenience Ratio	Decision Ratio
minimize value of new system	5/1	18.0	5/1	23.4
estimated values	2/3	2.4	2/3	3.1
maximize value of new system	1/5 (& 1/4)	0.7	1/5	0.9
Extreme Variation	Safety Ratio	Decision Ratio	Safety Ratio	Decision Ratio
minimize value of new system	5/1	12.0	5/1	7.8
estimated values	1/1	2.4	2/1	3.1
maximize value of new system	1/5	0.5	1/5	0.3

the resulting decision choice ratios are 18.0 and 23.4 for the University owned GMC and van systems respectively.

Conversely, when the convenience is minimized for the present system and maximized for the others, the corresponding decision ratios are 0.7 and 0.9. As a result, it can be seen that the effect of changing the convenience factor values, the present system is overwhelmingly favored or the two alternatives can be slightly favored. While the selection of the mode can be changed by the convenience factor values, the effect of this change is not considered significant. The choice ranges between strongly favoring the present system to slightly favoring the alternative modes. The University owned GMC system would be preferred for the extreme convenience ratios of 1:4 and 1:5 (University owned to present system) and University owned van system in only the 1:5 ratio. It is not felt that the effect of the convenience factor values on the concluded selection decision is significant as the possibility of these extreme differences in convenience between the systems is very minimal.

The other qualitative ratio investigated for the effect of the factor values was safety. In selecting the present system, corresponding safety values of 1 and 2 were given to the two GMC systems and to the University owned van system. When the safety value for the present system is maximized (equal to 1) and minimized for the University owned transit systems, the resulting ratios are 12.0 (University owned GMC system to present system)

and 7.8 (University owned van system to present system). If the safety value is minimized for the present system and maximized for the others, the resulting ratios are 0.5 and 0.3. The upper and lower limiting ratios for the comparisons between the present and the University owned GMC bus system is academic. As stated in the "Present (Upgraded) System" section of this chapter, the safety of these modes is equal since identical vehicles are used. Some variation could be attributed to driver effect, but this difference would be very difficult to determine and most likely very minimal.

While the difference in the comparison between the two GMC systems is irrelevant, the effect on the comparison between the present system and University owned system is important. The choice can range from strongly favoring the present system (7.8) to strongly favoring the van system (0.3). Here, it can be seen that the subjective scaling of the safety criteria can definitely affect the final decision. While the scaling values actually used in the selection decision are felt to be representative of the modes, the possible error introduced is evident. The best approach to resolving this effect of the safety factor would be to evaluate it in quantitative terms. One possible safety parameter, if available, would be accident rates. The safety ratios could be generated in terms of injuries and fatalities per million vehicle miles of vehicle usage or per million passenger miles. The use of these parameters does, of course, depend on the available compilation of them in usable form. If, however, the safety factor values

could be expressed in quantifiable units, more objectivity could be incorporated into the model resulting in a more substantiated decision.

In addition to the scaling values for the qualifiable criteria, the weighting values for the criteria ratios were also subjectively chosen. The weighting factors, in the form of exponents, were given the value of unity for the criteria of convenience, travel time, and safety. The annual cost to the University was given a double value of 2.

The total effect on the decision outcome of each evaluation factor ratio is significantly dependent upon the value of the exponent assigned to it. Thus, it is important that the appropriate weighting value be assigned to each ratio. For the comparison between the two GMC bus systems (see Table 4), the decision reversal point occurs when all exponent values are equal to unity. When all the exponents equal 1, the final decision ratio equals 1. If the cost factor ratio, favoring the present system, is raised to a higher power, the present system will be chosen. If either of the ratios favoring the University owned system, convenience and travel time, are raised to a higher power, the model will select the University owned system.

The decision reversal point is different for the comparison between the University owned van system and the present GMC bus system because of the different safety ratio. In order for the decision ratio to be equal to 1, the exponents of the convenience,

Table 4: Sensitivity Analysis:
Effect of Weighting Values

Comparison	Decision Choice Outcome	Convenience =Ratio Exponent	Travel Time xRatio Exponent	Safety xRatio Exponent	Cost xRatio Exponent
New GMC System / Present System	reversal point	1	1	1	1
	present*	1	1	1	2
	new	2	1	1	1
	new	1	2	1	1
New Van System / Present System	reversal point	1	2	1	1
	present	1	1	1	1
	present	1	2	1	2
	present*	1	1	1	2
	new	2	2	1	1
	present	1	2	2	1

*Actual mode chosen given the corresponding exponents of the ratio factors

of the safety, and of the cost ratios must equal 1 while the exponent for the travel time ratio is equal to 2. Again, if those ratios favoring the University owned system are raised to a higher power, that system will be chosen. If, on the other hand, the exponents of the ratios favoring the present system are raised, it will be selected. Thus, it can be seen that the importance of the weighting values for the particular criteria ratios given (see Table 4) depend on which ratio factor is more weighted rather than by the magnitude of the weighting value. In the decision that was made in this study, the cost criterion was given a higher degree of importance (more weight). It is felt that, given a real situation, this cost factor would be the most influential criterion in deciding which type of transportation system to implement.

The technique used in this thesis to select the system is not a rigorous, comprehensive selection process. It is, however, easily employable and applicable to the transportation study of this housing complex. The resulting choice made, while more the result of an academic illustration of a selection than an exacting scientific analysis, is conclusive from the input information available and, thus, acceptable. Therefore, it is recommended that, based on the prescribed assumptions and the survey returns collected, the most feasible campus shuttle service for the residents of Christopher City is the maintenance of the present system (upgraded and subsidized) operated by the Tucson Transit Corporation.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

As a result of this transportation study of Christopher City, various conclusions were reached. From the questionnaire surveys returned by the participants, the travel characteristics of the residents of this housing complex were determined. To meet the travel needs of the occupants, transportation systems were reviewed and one was chosen as the most feasible. Due to the limited scope of this thesis, many assumptions were made to conserve time and space. Although these assumptions were made as accurately as possible, their accuracy is restricted by the lack of detailed information. In this final chapter, both the conclusions reached and proposed methods to refine them are discussed. In addition, a few useful applications for this thesis are proposed.

Conclusions

The twofold purpose of this thesis was to determine the travel trends of the Christopher City residents and to propose a feasible means of mass transportation for them. In accomplishing these objectives, conclusions were reached concerning each one.

It was concluded from the survey that 647 direct passenger round trips per school day were made between Christopher City and

the University campus. Most of the one-way trips from Christopher City to the campus were started early in the morning. Over two-thirds of the trips were initiated between 7:00 and 8:15 in the morning. For the return trips back to the housing complex, the departure times were more dispersed throughout the day. However, there did exist some peaking in the late afternoon. Just under one-half of all the daily departures from the campus occurred between 4:30 and 5:00 p.m.

Another interesting finding of the study from the returned surveys was the potential patronage of a bus system that was convenient and inexpensive. Although 70 percent of all trips were made at that time in an automobile, the answers to one of the survey questions indicate that up to 65 percent of the total trips might be conducted on a bus system. It is known that not everyone who indicates a potential bus usage will in fact use the bus, but this large potential usage percentage did indicate a strong desire for an improved shuttle bus system to and from the University.

From the evaluation of the proposed alternatives, the conclusion was reached that the public bus service was the most feasible transportation system. When the effects of the selection criteria were evaluated together in the decision model, the transportation system operated by the Tucson Transit Corporation proved best suited to meet the needs of the Christopher City residents. It was favored to either of the University owned systems. Therefore, the recommendation was made that the University not attempt to operate

its own shuttle service for Christopher City. Instead, the University should promote the use of the presently operating public system by subsidizing one-half of the existing round-trip fare. In this manner, the needs of the residents would be most satisfactorily met and the financial burden reduced for the University.

Proposed Research

As mentioned in the last chapter, various assumptions and approximations are made with the available data. Various conditions are assumed due to incomplete information. Changing circumstances and unavailable data necessitates such assumptions. The approximations used chiefly concern the cost estimation of the various factors of the proposed alternatives. Considerable time was spent consulting informed personnel to make use of their general knowledge. It is felt more beneficial to allocate time to the total picture of a modal system than to perform detail cost studies of the many components when readily available from knowledgeable sources.

The results or findings of an initial study will often propagate studies of related areas. From the parent study, other analyses will be generated to investigate intermediate findings or to apply a final conclusion to other similar situations. A few suggested studies are presented below to use the results of this thesis. In addition, proposed studies are recommended to refine the present study.

1. The questionnaire, from which the travel characteristics are determined, was distributed in May 1972. Since this time, two changes have been instituted which could affect the results of the survey. These include a change in class starting times (from forty minutes past the hour to on-the-hour times) and increased service from the Tucson Transit Corporation. It is not felt that these changes have significantly altered the final conclusion, as the capacities of the reviewed alternatives are based on hourly capacity and present class times. The increased service may have increased bus ridership, but probably not to a significant extent since the other important factors--comfort, travel time, safety, and trip fare--have remained constant. However, to more properly substantiate the previous travel patterns, a follow-up survey should be conducted. In addition to determining any adjustment in trip times, the new survey could also be used to specifically uncover modal preferences of the actual riders--the residents of Christopher City. This information was obtained in the initial survey only indirectly and was not specifically sought. The review of the literature revealed a general area of modal preferences by riders. But, because of the varying relative importance of these desires for each of the studies reviewed, it was felt important to determine the specific preferences of Christopher City residents.

2. The comparison of the alternative modal proposals for this study was conducted with ridership (of the system) assumed

constant. Usage is based on 32.5 percent patronage between existing and indicated potential ridership. This, perhaps optimistic, ridership is rather arbitrarily assumed as there are no available techniques to systematically and accurately determine actual usage from indicated usage. Another possible means of mode comparison is to determine the feasibility of a University operated transit service based on varying degrees of system usage according to individual alternatives. A study of this nature would serve the purpose of indicating any trade-off between the cost of presently providing the campus parking spaces for the large number of automobile commuters from Christopher City and the cost of a transit service with reduced parking spaces. Of course, an inherent problem is to accurately predict the number of attracted riders by mode. Even with the use of a survey, this problem is still critical as in this thesis. The ubiquity of this problem is the basis for the next recommended research.

3. An effort should be undertaken to determine the relationship between the number of riders indicated by related surveys and the actual ridership occurring once a system is implemented. In the equality of $P_A = KP_I$, with P_A and P_I being the actual and the indicated patronage, the coefficient, K, is the key to useful application of survey results. Avenues of approach to accurately determine this relationship could include before-after studies of recently installed transportation systems and analysis of modal-split techniques used in future traffic volume predictions. Various

feasibility and origin-destination studies are conducted before mass transit services are executed. After demand trends are established following the start of service, a comparison can be made between predicted and actual usage. This type of comparison would be significantly pertinent if any public surveys are used in the prediction process. "Modal-split" is a method used in determining the future traffic volumes in some urbanized area. As stated by the American Society of Civil Engineers (1968, p. 52), procedures of this type "are developed to determine the proportional division between transit and private automobile usage . . ." Since any mass transit system proposed for the University essentially draws riders from their automobiles, the details and characteristics of these modes could be useful in determining the relation between indicated and actual ridership.

4. Scheduled to be completed for occupancy in the spring of 1974 is a new married student housing complex located southeast of the main University campus on the 2100 block of Broadway. Although only in the initial planning stage, this complex is to provide 250 two-bedroom apartments at first, followed by an additional 100 units in the future. In order to provide adequate transportation facilities for the residents of this new complex, a study should be undertaken in the planning stages investigating possible transit alternatives. The findings of this thesis (and any resulting spawned studies) can be used directly in consideration of transit service for this new housing development. The results can be

influential in deciding between a University owned and operated system or using Tucson's existing public transit. If the latter choice is selected, then ample time must be allocated to make the necessary arrangements with the Tucson Transit Corporation.

5. In the subsection "Modes of Travel" of Chapter III, the various methods of transportation used by the residents is described. It is of interest to note that, of the non-automobile modes, the bicycle is the most frequently used means of personal transport. Of the total number of trips made to the campus, 14.3 percent are made with the use of a bike. This significant utilization of this mode reflects the phenomenal increase nationwide of bicycles. Because of the significant use of the bicycle by Christopher City residents, it is felt an investigation into the establishment of a delineated bikeway is warranted. This type of study could also serve as a possible initial step in the establishment of a delineated bike-route system throughout Tucson. A typical feasibility study would involve the choice between the three levels of bike/vehicular traffic: completely separate right-of-way (ROW), restricted on-street ROW, and shared ROW (bikeway designated by signs only). Each of these has inherent advantages and disadvantages that must be compared. Some specific factors to be considered include topography, attitudes of route-adjacent homeowners/storeowners, vehicular traffic conditions (speed, volume, roadway dimensions, etc.), installation and maintenance costs, lighting, and cyclist safety (traffic and criminal). Sources are available

detailing the effects of these variables and outlining special planning considerations. A potential bike-route for Christopher City-main campus travel is by way of Columbus Boulevard, Glenn Street, and Mountain Avenue. This bikeway consists of 5.4 miles of travel through four signalized intersections. Other routes are available that could include passage near the medical campus. Detailed information concerning the aforementioned variables would be collected to determine the most feasible route and the most feasible level of bike-vehicular traffic separation.

APPENDIX A

ANALYSIS OF HIGHLAND AVENUE PARKING LOT

Summary

At The University of Arizona, the parking of automobiles has long been a problem. Facilities are inadequate in providing enough spaces for the University body, especially the students. Early in the morning of each school day, the off-street parking lots are filled, forcing students to illegally park on campus or to park several blocks from campus.

One type of parking facility is the self-parking, pay parking lot. There are three of them on campus, and they appear to suffer the same problem as the other parking facilities. They fill up early each morning and remain full until mid-day. By studying these lots, an insight can be obtained into the frequency of their use.

To analyze the time character of pay parking lot users, the non-attended pay parking lot at Highland Avenue was chosen for study. It is a self-parking lot with an entrance fee of $0.25. The lot has one entrance and one exit, both with gates, and has a usable area of about 29,800 square feet.

The study is broken down into two parts. First, data was collected through the use of manual and cumulative traffic counters.

Counts were taken throughout the day for several days. From this frequency data, the time and number of parkers is determined. The second part of the study is the stall arrangement in the lot. The present layout consists of right angle parking, accommodating ninety-five cars. In an effort to redesign the lot to allow for more spaces, two alternate stall configurations are presented and discussed later (Allocation of Parking Spaces).

Results

The results of the study are presented below in two parts: 1) Usage Analyzation and 2) Allocation of Parking Spaces. The figures used to present the information are located following the report discussion.

Usage Analyzation

In this section, the counter data is broken into daily and hourly intervals to show the time frequency of the parking lot usage. The data is divided into four categories: 1) Hourly Entrance Frequency, 2) Hourly Entrance vs. Departure, 3) Hourly Accumulation, and 4) Daily Usage Frequency. For each group, the data is presented in graphical form and discussed.

Hourly Entrance Frequency. The arrival time of cars shows when and how many cars use this lot. Counts were made for five days and the results are shown in Figure 1. Data was graphed for five days. For only one of these days, Thursday, 3/2, was the data taken over a major part of the day (8:00 a.m. to 12:00 p.m.).

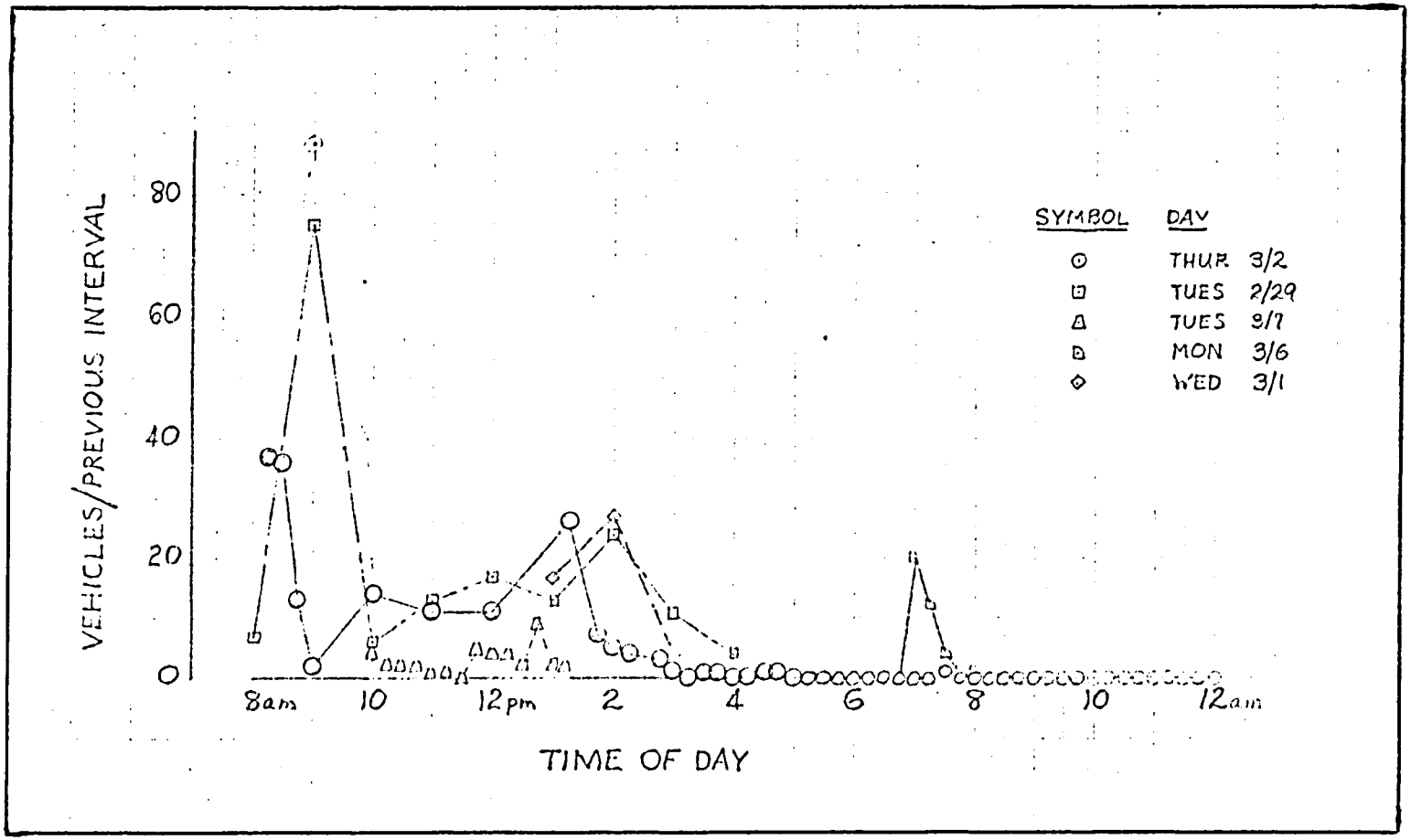

Figure A-1. Hourly Entrance Frequency

However, the information for Tuesday, 2/29, covers a significant portion of the school day also (8:00 a.m. to 4:00 p.m.).

From the graph, it can be seen that the peak arrival time is between 8 and 9 o'clock in the morning. The curve for 3/2 shows large numbers of cars arriving during the first two quarters, while 2/29 shows a single, larger group arriving the last quarter of the hour. After this early initial peak, the number of arrivals greatly tapers off and remains relatively constant until the early afternoon. While at first glance, it looks as if the data for the two Tuesdays (2/29 and 3/7) for the time period are inconsistent, this is not the case. On 3/7, interval counts were taken for fifteen minute intervals which will give lower interval totals than for the hourly intervals on 2/29. If the quarter hour counts of 3/7 are totaled hourly, the totals will agree closely for the two days.

Following the morning lull, the arrival rate between 1 and 2 o'clock in the afternoon increases to about double the previous later morning rate. All the data for this time period is consistent. Finally, the arrivals taper off to near zero around 4 p.m. with few cars entering after this time. The only exception is for the Monday data. Here, a large number of cars enters just before 7 p.m. and continues for an hour. This could be due to an evening class which is held in a building near the lot.

Hourly Entrance vs. Departure. Another correlation of data is the relationship between the number of arriving and departing

cars. This information is presented in Figure 2. Data is shown for two days: Thursday, 3/2, from 8:00 a.m. to 4:00 p.m., and Tuesday, 3/7, from 8:15 a.m. to 1:15 p.m.

Again, if the departure data for 3/7 is totaled hourly, the data for both days give fairly similar distributions. A significant conclusion cannot be drawn from the Tuesday data because of its narrow time span, but the Thursday data is more useful. It shows that until the lot is filled, by around 9:00 a.m., there are few exits. Since the lot is designated full by a security guard between 9 and 10 a.m. (with the "full" number being inconsistent), it is difficult to determine when the lot is closed to entry. From the data, though, capacity was reached around 10 o'clock since up until this time, more cars entered than left.

At 10:30, the number of cars leaving is greater than the number entering. This means that from this time on, the lot is not filled to capacity. However, since the exiting data closely resembles the entering data, the lot has approximately a constant number of parked cars until 3 p.m. From 3 to 4 p.m., the cars begin emptying out. Although not shown, the lot is emptied by about 6:00 p.m.

Hourly Accumulation. As a summary of the previous two graphs, a third graph (see Figure 3) combines the information into an hourly accumulation. This graph presents data for 3/2 and for 2/29.

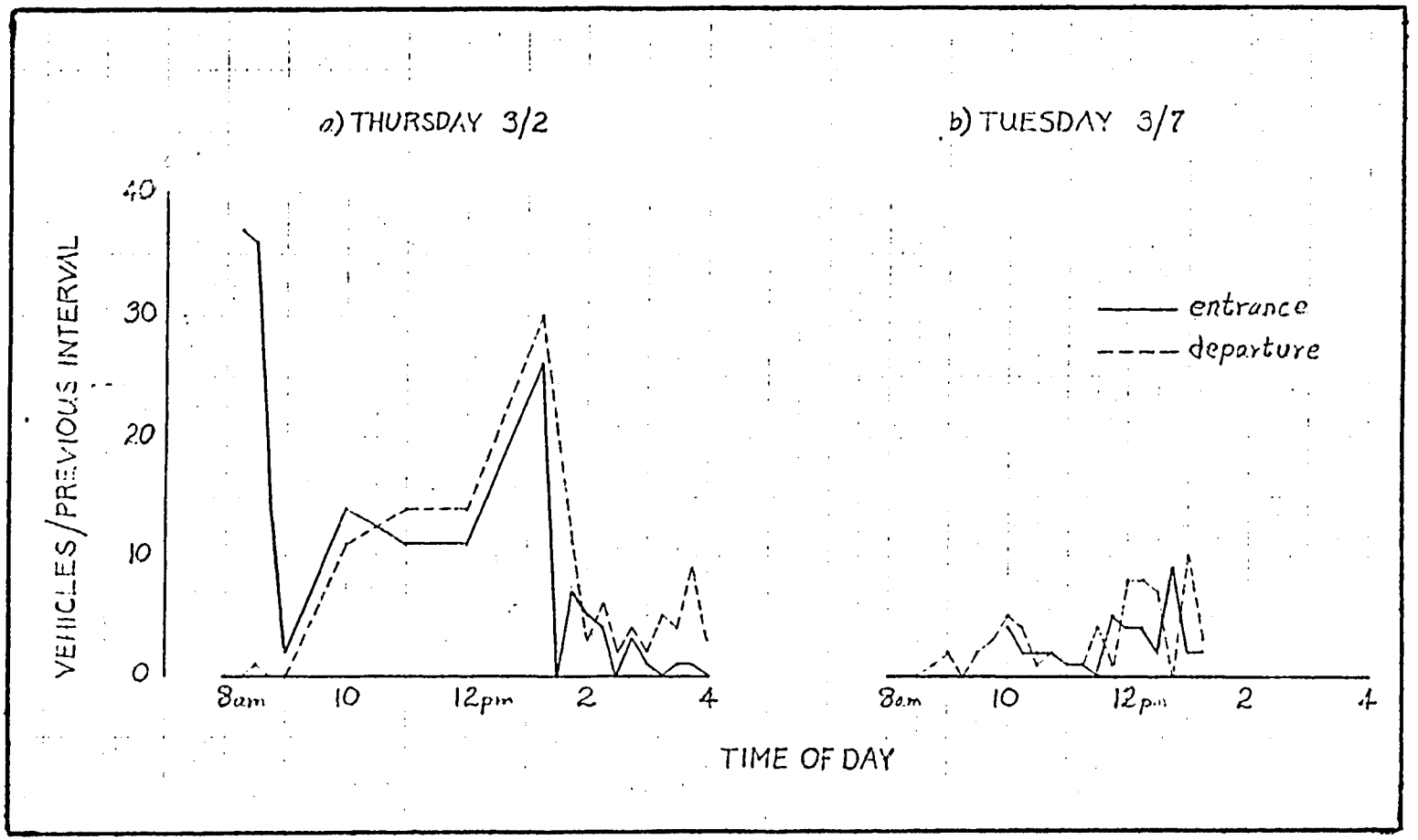

Figure A-2. Hourly Entrance vs. Departure

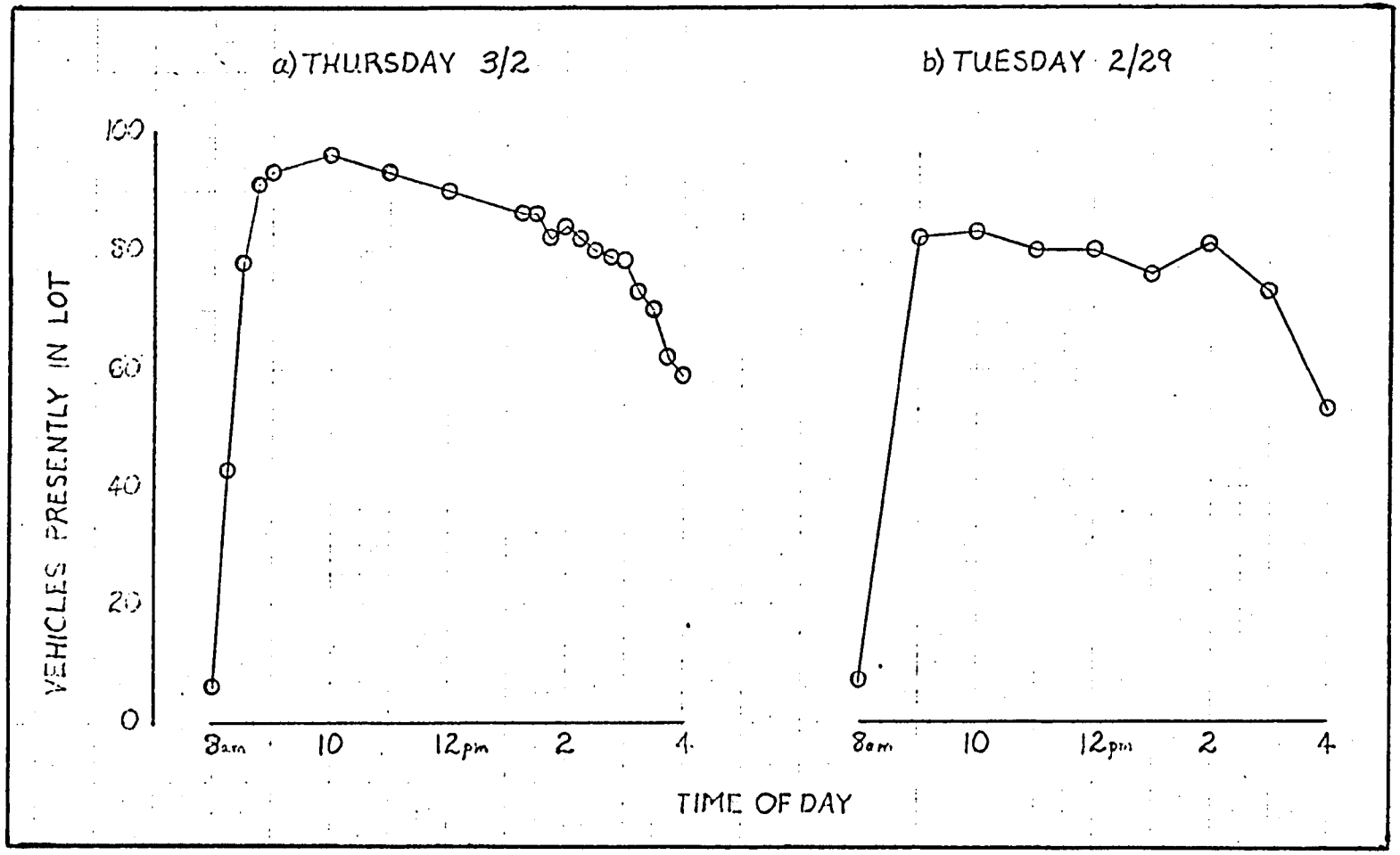

Figure A-3. Hourly Accumulation

On the particular Thursday, the capacity of ninety-six cars was reached by 10:00 a.m. On the Tuesday, the capacity of eighty-three was again reached by 10:00 a.m. The difference in capacity levels is probably due to the variance in the "full" designation by the security guard. In agreement with the conclusion of the previous section, the lot reaches its peak capacity by 10:00 a.m., slowly tapers off to about 3:00 p.m. with the number of cars parked sharply reducing from 3 to 4 p.m.

Daily Usage Frequency. To arrive at a daily usage count, the number of exits were totaled for the day. Totals for six of the seven days of the week were tabulated and are presented in Figure 4 (note two points for Tuesday, because of the two Tuesdays studied). The data for Wednesday was too incomplete for any reasonable, accurate total.

It should be noted that the exit data for the two Tuesdays is incomplete. On 3/7, the exits were counted until 1:20 p.m., while they were counted until 4:00 p.m. on 2/29. However, since the counts were very close for the same times for the Tuesdays and both Tuesday counts closely resembled the Thursday count, the data for the Tuesdays was extrapolated for the whole day in the same manner as the Thursday data. It is felt that this extrapolation is accurate and gives a true picture of the total exits on a Tuesday.

Referring to the graph, it is seen that on Monday, the lot is used more than any other day. On this day, 226 cars used the

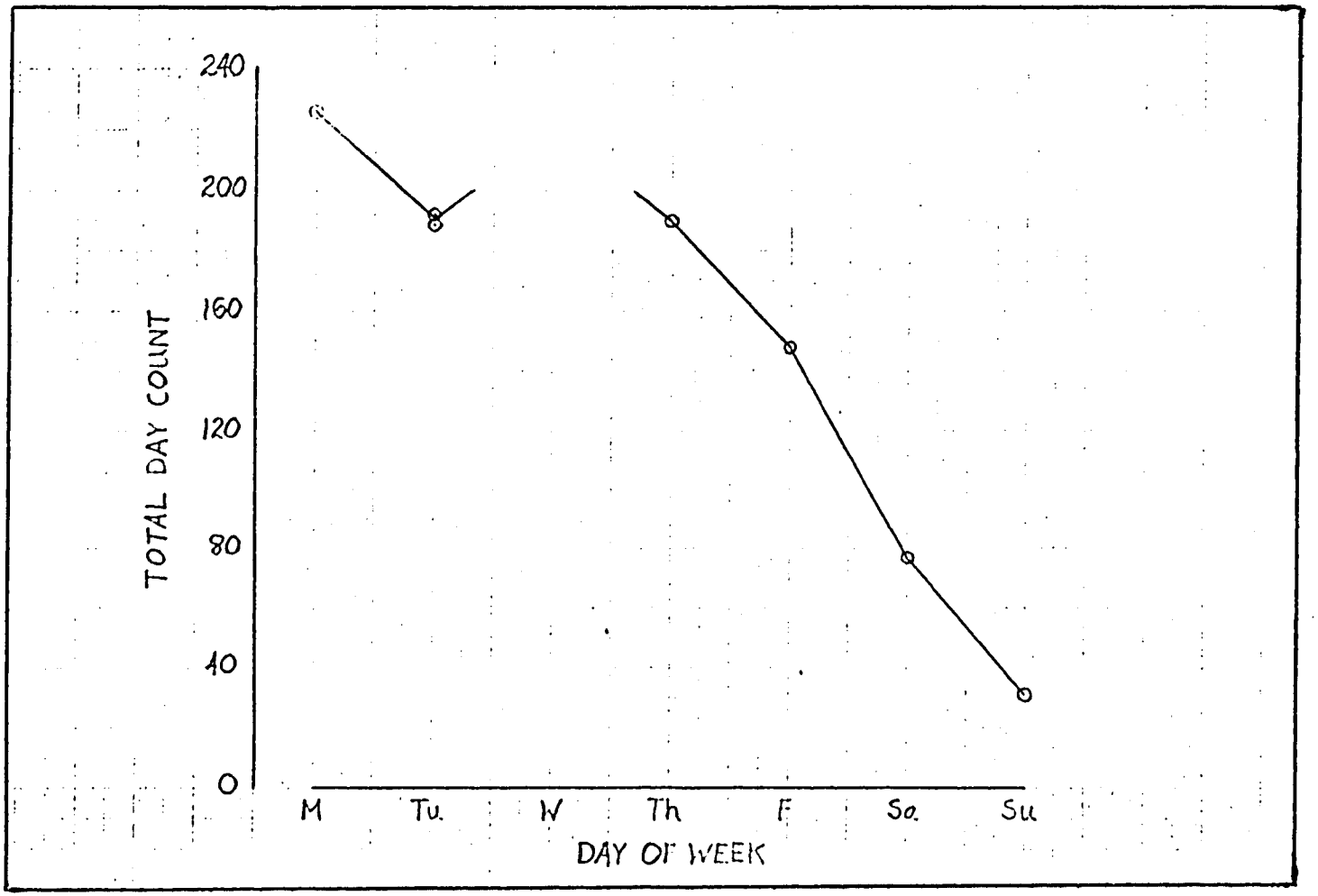

Figure A-4. Daily Usage Frequency

lot. Tuesday and Thursday are the next busiest days, both having about 190 cars/day. Another interesting point is the relatively low usage of the lot on Friday. It had been previously assumed that the demand for parking was equivalent on Mondays, Wednesdays, and Fridays and the same for Tuesdays and Thursdays. While the latter part of the assumption is verified, the initial part is not. There is a much lower demand on Friday than expected.

Looking at the turnover ratio, we see that it is 2.38 for Mondays and 2.00 for Tuesdays and Thursdays (based on a maximum capacity of ninety-five cars). If we assume that the total for Wednesday is about 210 cars, we get an average turnover of 2.03 for the Monday-Friday schoolweek. This signifies that each parker, on the average, uses a space for about one-half of a schoolday.

Allocation of Parking Spaces

In this part of the study, an investigation was made into the layout of the parking spaces in the lot. In the present configuration, the lot can accommodate ninety-five cars, utilizing the right angle arrangement. Figure 5 shows this arrangement, based on spaces of 8.5 x 19 feet, with the corresponding measurements. Although the lot is capable of the ninety-five car capacity, often, cars are not parked in the fashion shown because the parking lines are practically non-visible in the center of the lot. When this occurs, the capacity is lowered and as few as eighty cars can use the lot.

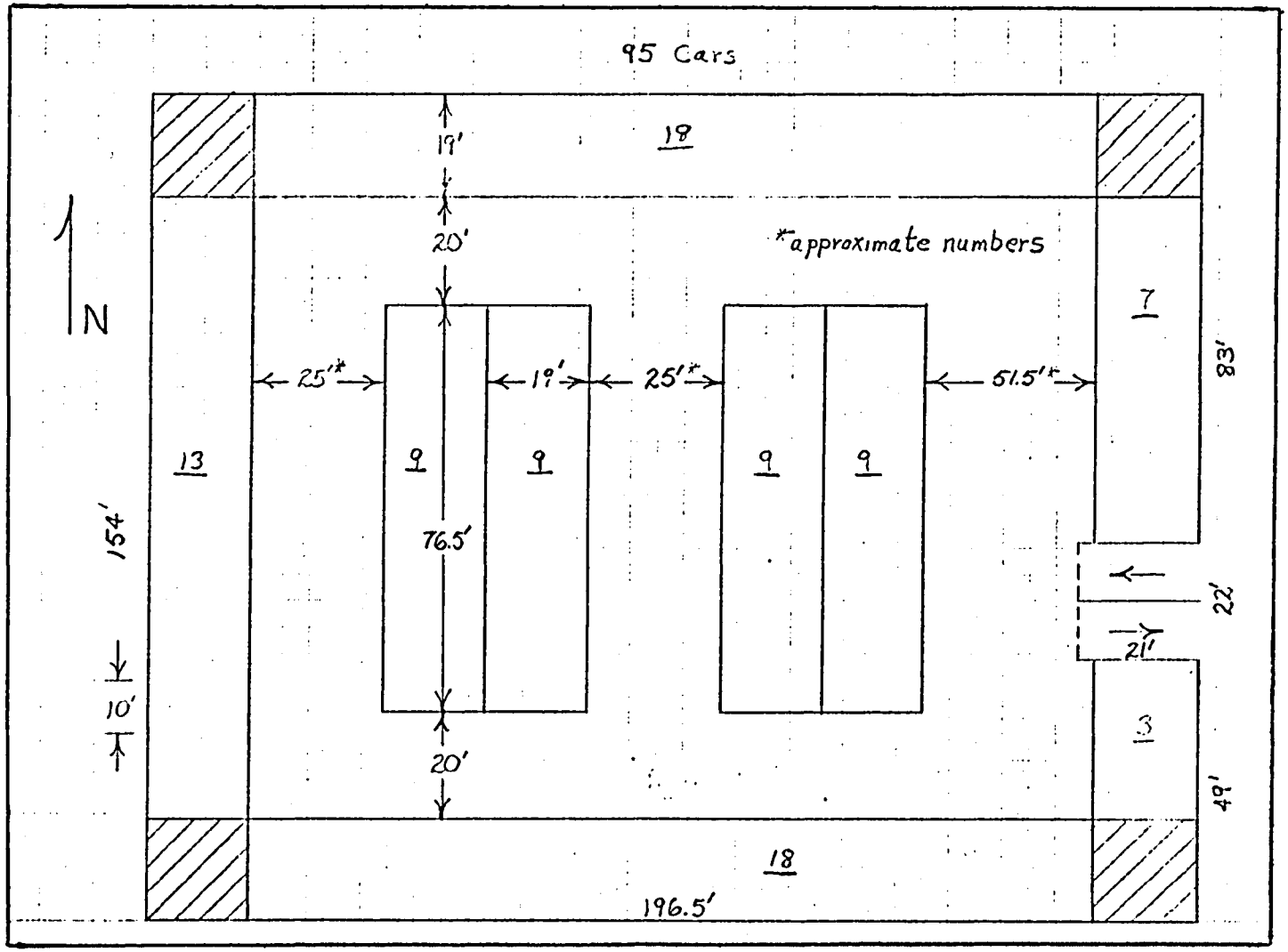

Figure A-5. Present Stall Arrangement

To achieve maximum efficiency in a parking lot, the right angle arrangement should be used (Baerwald, 1965, Handbook, p. 480). On page 479 of this Traffic Engineering Handbook, the recommended area per car (90^{o}, 8.5 x 18') is 296 square feet. The Highland Avenue lot, with its usage area of 29,800 square feet allocates 29,800/95 = 314 square feet/space. Since the existing efficiency is very close to that recommended, very few spaces could be added.

Figures 6 and 7 show two proposed alternate layouts. For both proposals, the spaces are 8.5' x 19' and the aisles between perpendicular rows are twenty feet, as in keeping with the present design features. In Figure 6, the rows are all aligned running north and south with only a few angled spaces on the western end. The total capacity for this configuration is only eighty-five, ten less than the present capacity. In Figure 7, the rows chiefly run east and west, with a few angled spaces on the south end. This allotment provides for ninety-two spaces which is close, but still less than the present configuration.

Conclusions

During the procurement of data, there is one chief source of error--the counters. The error originates in the clock mechanisms and in the sensing device. The clocks in the continuous counters would sometimes fail, giving an inaccurate time distribution. Because the counters, continuous and manual, received impulses pneumatically from the road tubes, the speed of the car at

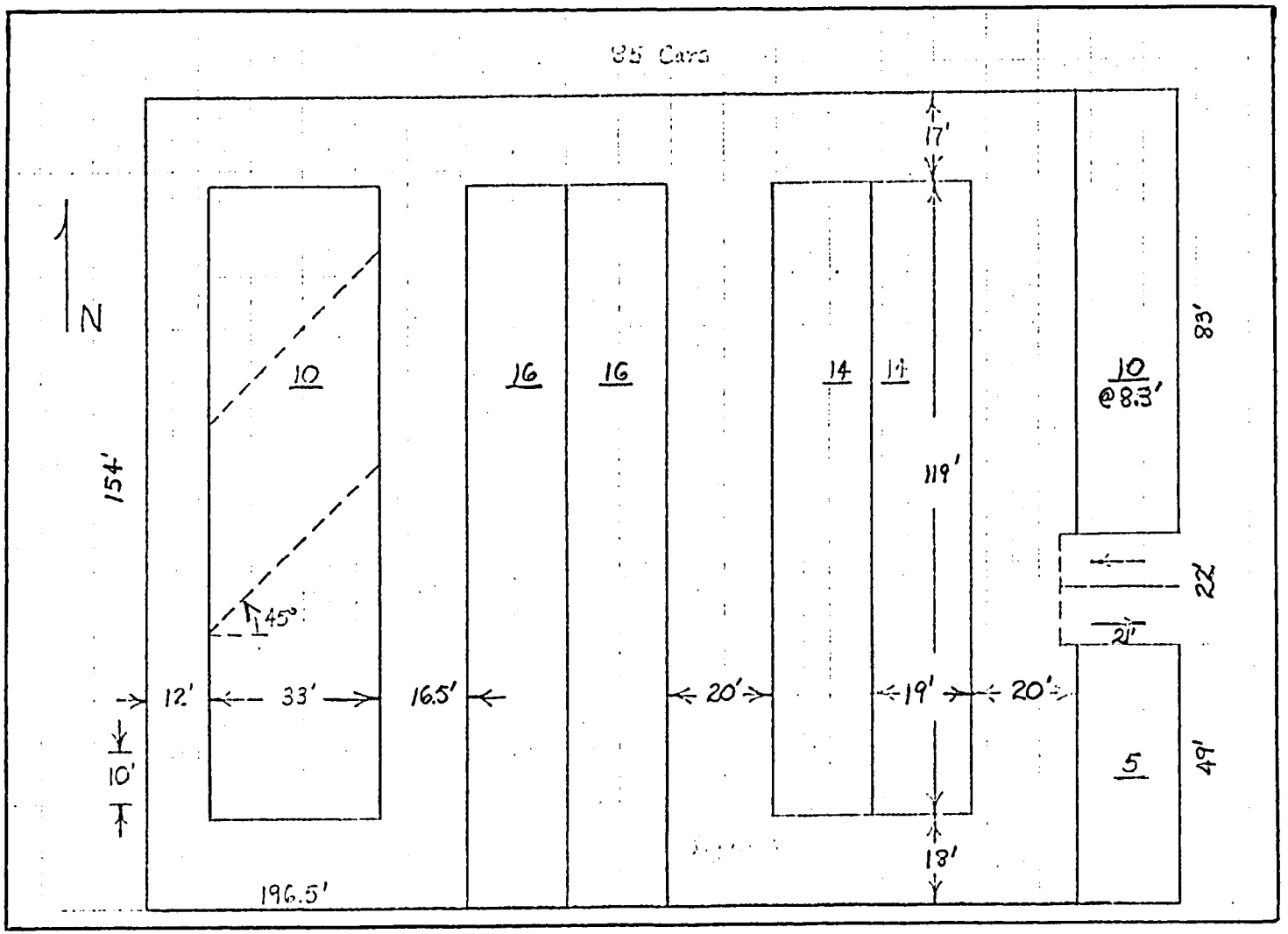

Figure A-6. Alternate Stall Arrangement I

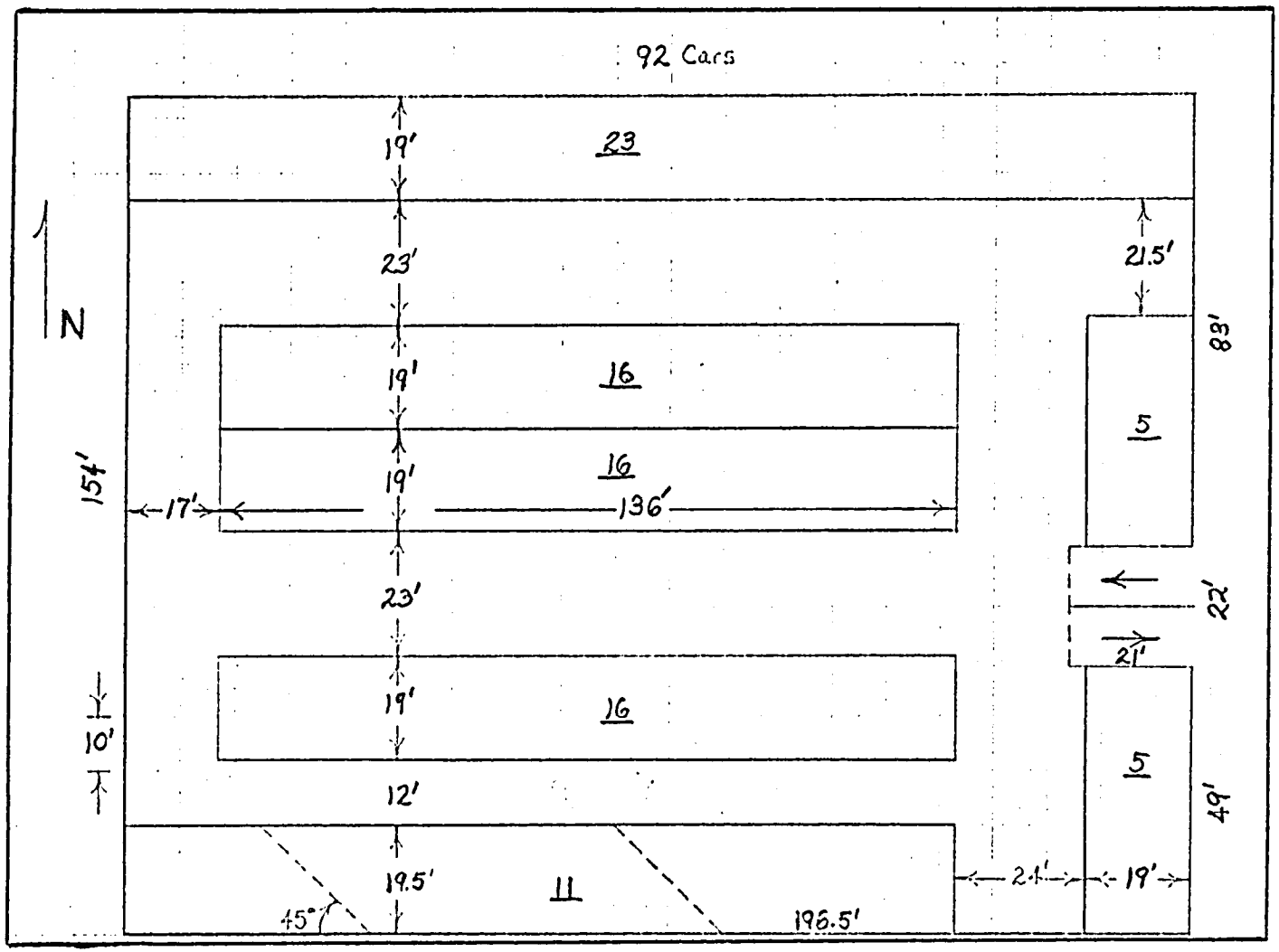

Figure A-7. Alternate Stall Arrangement II

the tube affects the amount of impulse sent to the sensing mechanism. However, this source of error is believed minimal, since a check on the entrance counter revealed only one car in eighty-eight was missed for a 1.14 percent error.

In spite of the error present, the data does reveal consistent and useful trends. From the study, five basic conclusions can be shown:

1. There are two main arrival peaks each day: the largest occurring at 8-9 a.m., and a smaller one at 1-2 p.m.

2. The lot is filled to maximum capacity at 9-10 a.m. It remains filled at about 90 percent capacity until 3 p.m. when the lot begins to empty out rapidly.

3. The schoolday of maximum use is definitely Monday; Tuesday and Thursday have equal demands, but to a lesser extent.

4. The weekday parking lot user, on the average, uses a space in this lot for one-half of the schoolday (8 a.m.-6 p.m.).

5. The present stall arrangement provides for the maximum number of spaces possible for the given usable area.

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