CHANGE OF MODE PARKING FACILITIES

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BY

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JOINT HIGHWAY RESEARCH PROJECT

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Final Report

CHANGE OF MODE PARKING FACILITIES

TO: J. F. McLaughlin, Director
Joint Highway Research Project

February 15, 1972

Project: C-36-74C

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

File: 3-9-3

Attached is a Final Report titled "Change of Mode Parking Facilities" by Usamah R. Abdus-Samad, Graduate Instructor on our staff. The research reported was directed by Professor W. L. Grecco. Funding for the project was primarily from grants from the General Electric Corporation. The report is presented to the Advisory Board of the Joint Highway Research Project for information as is customary for non-ISHC sponsored highway or highway-related research.

The report includes an analysis of important physical, operational and locational characteristics of change of mode parking facilities experienced by 26 agencies covering 73 rail and 20 bus facilities. A model for predicting the demand for change of mode parking facilities is also developed. A study of the economic feasibility of change of mode parking in contrast to use of the automobile for the total trip is also included. Finally the design criteria are determined using the findings of this study for a hypothetical change of mode lot in Indianapolis.

The report is presented to the Board for information.

Respectfully submitted,

Harold L. Michael

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ABSTRACT

Abdus-Samad, Usamah Rashrash, Ph.D., Purdue University, January 1972. Change of Mode Parking Facilities. Major Professor: William L. Grecco.

This thesis reports the results of a study concerned with the determination of successful design criteria for change of mode parking facilities in any medium sized or large U.S. city.

The input to the computerized package which determines the successful design criteria, consists mainly of the characteristics of the city, the transit system and the location of the parking facility. The output consists of an estimate of the change of mode demand, costs and benefits of the change of mode parking facility, and the design criteria that optimized the community benefits accruing from the provision of the parking facility.

Ninety-three change of mode parking facilities in ten different cities were used in the study. Data were collected through a survey conducted by mail. Over three hundred and fifty questionnaires were sent to approximately sixty change of mode parking facility operators. One hundred and ninety usable replies from more than twenty parking facility operators were received.

The change of mode demand is estimated by a prediction equation developed by using linear regression analysis. The prediction equation was tested for its applicability by using separate data furnished by the Institute of Traffic Engineers. The economics of change of mode parking facilities are given by a linear regression equation developed from simulated data. Change of mode parking facility usage was studied through the use of analysis of variances techniques.

The models developed can be used to determine the most economical design characteristics of any given change of mode parking facility. For any given transit station the models can also be used to select the best alternative among several proposed parking lots.

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CHAPTER 1: INTRODUCTION

The essence of the urban transportation problem is that a large portion of urban trips overlap in time and space. Many persons travel to the same destination, during the same time period, thus resulting in heavy congestion on arterials leading to the downtown during the rush period. The passenger car being the most preferred mode of transportation helps in compounding the problem by adding the terminal parking problem to that of the arterial congestion.

Transportation engineers, with insight into the urban dilemma, have long advocated the design of a coordinated and integrated system. A system that utilizes each different transportation mode where it is most efficient, and that provides for a smooth interface connection between the different modes qualifies as a coordinated transportation system. Change of mode parking facilities, also known as park 'n ride lots, perform the role of a connecting link between passenger car and mass transit. The passenger car is used in the collection of the trips in areas of low density trip ends. At the same time, change of mode parking increases the demand for mass transit along established travel corridors, by increasing the service area of transit stations. Finally, change of mode parking reduces the demand for parking in downtown areas, by diverting such demand to locations of lower land use density and lower land value.

Purpose and Scope

There are four objectives of this research. One, is to statistically analyze the effect of the physical, operational, and location characteristics of change of mode parking facilities on their usage (percent occupancy of the lot). Factors such as the adequacy of the transit system and the metropolitan area characteristics would also be included in the analysis.

The second objective is to predict the demand for change of mode. This is achieved by developing a multiple linear regression equation whose independent terms are a measure of the physical, operational and location characteristics of the parking facilities. An acceptable prediction equation must possess a logical sensitivity, in addition to satisfying all statistical constraints. The equation in question must also be easily applied.

Objective three is to determine the economic feasibility of change of mode parking in contrast to the use of the private automobile for the remainder of the trip to downtown. The economic feasibility is studied on the basis of community-wide savings and costs. The economic analysis is based on the assumption that (a) the change of mode parking is not going to affect the level of congestion downtown or in the arterial corridors leading to it, and (b) that the amortization costs of both the highway system and transit system will not be included.

The last objective is to determine the design criteria for a hypothetical park 'n ride lot in Indianapolis, Indiana. This is to be accomplished by combining the results of objectives two and three, while maximizing the savings that accrue to the community from the usage of these parking facilities.

The main interest of the project is the study of CBD oriented change of mode from passenger car to either bus or rail or a combination of the two. The project is performed on a nation-wide basis, and does not study interchange parking with its associated car pooling. The study concentrates on specified and well defined facilities. Parking away from these facilities such as at the curb or at nearby service stations are not included. The reason for this exclusion is that both instances are deemed to be not amenable to quantitative analysis. Data collection, and the analysis of factors that affect park 'n ride demand at the curb or at service stations are extremely difficult tasks.

Only those parking facilities that are used solely for both park 'n ride and kiss 'n ride are of interest.

Facilities in the fringe of the CBD, and in regional centers within the metropolitan area are not to be studied. A substantial number of CBD fringe parking facility users walk to their destinations in the downtown area. In such a case the ride portion of the change of mode phenomenum is missing, and the parking demand at such facilities is therefore an inflated and biased estimate of park 'n ride demand. Also omitted are parking facilities in regional centers which besides serving the demand for park 'n ride, are also used as terminals for shopping and business trips that can be completed by walking.

The demand for change of mode parking in cities that behave as satellite centers, and do not form an integral part of the neighboring metropolitan area, is deemed to be mostly affected by the specific regional employment conditions. Such demand is less sensitive to the parking and transit characteristics of the facility. The prediction of the demand for change of mode under these conditions is therefore highly unreliable, and for this reason such facilities are not included in the study. In conclusion, change of mode parking lots are studied in all metropolitan area locations that have not been excluded in the above discussion.

History

Change of mode parking lots have been in use for quite some time in Chicago, Boston, Cleveland, New York and Baltimore. Several lots were already in operation before the second world war came to an end (1)*. Operation-wise, those lots perform two types of service. They either are located in the fringe of the downtown area, or in satellite centers outside the metropolitan area. The first type caters to the distribution of trips within the CBD (2), while the second performs what today one calls park 'n ride in conjunction with commuter trains (3).

In the mid fifties Cleveland was the first city to introduce systematic change of mode parking on a wide scale, and in conjunction with a new rail rapid transit system. In the early sixties, Milwaukee instituted change of mode parking with a limited express bus system operating on newly constructed freeways. During that same period, Boston analyzed the effect of parking fees on the usage of its change of mode parking lots (4). In the mid sixties, San Francisco was planning and advancing physical design criteria for change of mode lots at most of its proposed transit stations (5). At the same time the National Capital Region analyzed the economic feasibility of change of mode parking, and the factors affecting the usage of its lots. The analysis was based on a nation-wide survey (6).

The Federal Highway Act of 1968 authorized a demonstration program, using federal aid funds for the acquisition of land adjacent to the right of way on any

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*Numbers in parentheses refer to entries in the list of references.

federal-aid highway system, and the construction of change of mode parking facilities thereon or within the right of way, to serve urban areas of more than fifty thousand population (7). Shortly thereafter, the United States Senate Subcommittee on Housing and Urban Affairs held hearings on how better transportation could be achieved. Towards this end and based on the experiences in Milwaukee, Bruening advocated the use of change of mode parking (8). During that same period the New York and Chicago metropolitan areas instituted change of mode demonstration projects using federal funds (9,10). Wilbur Smith and Associates, in a National Cooperative Highway Research Project report listed 'design criteria for successful change of mode parking' among 256 needed research projects (11).

The National Capital is presently making plans for the construction of change of mode facilities in conjunction with express bus and reversible lane service on the Shirley Highway Corridor (12). The number of existing change of mode parking facilities in the United States stands at around two hundred and fifty. This estimate excludes passenger car-to-commuter trains change of mode, and car pooling facilities.

Recently, the Institute of Traffic Engineers finished the first comprehensive survey of change of mode parking facilities in the United States (13). One hundred and seventy nine facilities were investigated in this study.

The stage is now set to use the knowledge acquired from the experiences of many cities, and from the surveys and analyses made.

Outline and Methodology

The report herein presented is made up of eight Chapters, the first of which is the introduction. The second is a presentation of the related work done in the field of change of mode parking. The need becomes apparent, at the conclusion of the review, for predicting change of mode demand, for determining its economic feasibility, and for providing successful change of mode parking criteria.

Chapter three is a discussion of the data items, the method of their collection, and the coding procedure employed. An explanation and discussion of the method used in developing aggregate variables which affect change of mode lot usage and park 'n ride demand is also given. The research is based on a survey involving ninety three parking facilities in ten different metropolitan areas. Where data were available, several observations were made on the same facility. One hundred and ninety observations were taken to account for changes in facility characteristics and demand.

The fourth chapter presents the statistical analysis for change of mode parking lot usage. Repeated two-way analysis of variance is the method used. This procedure makes it possible to separately analyze the effect of the aggregate variables on parking lot usage, irrespective of possible intercorrelation between independent variables.

The next chapter discusses the development of the park 'n ride demand prediction equation. The method of analysis used is that of multiple linear regression. The independent variables in this regression analysis are the aggregate variables that were developed in chapter three, and found significant in the analysis of variance of the previous chapter. A discussion of the sensitivity of the prediction equation is included, and a test of its applicability is also given.

Chapter six presents an analysis of the economic feasibility of the change of mode process. The analysis is based on a comparison of travel costs by passenger car with and without the use of change of mode facilities. The change of mode process is formulated into a deterministic model and in the form of a computer program, the output of which is the net savings that accrue to the community. Subsequently, capital investment and running costs of the parking facilities are added. The data for this analysis is collected from the existing body of literature, and average values are used exclusively.

The seventh chapter applies the change of mode demand equation and the economic analysis to determine the design criteria for a hypothetical facility in the city of Indianapolis. For this purpose, a computer program is written to search for the optimum design criteria.

The report ends with a set of conclusions, and recommendations for further research .

CHAPTER 2: RELATED WORK

The bulk of the literature in the field of change of mode concentrates on three themes. The first group presents the need for change of mode, the feasibility of such an approach and its effects on the transportation system. The second theme is to summarize change of mode expreiences. In the main, such summaries deal with a description of the characteristics of change of mode parkers and facilities. The final theme reports on proposed and established physical design criteria of change of mode facilities, and on qualitative analyses of the factors that affect the success or failure of change of mode facilities. Very seldom are general design criteria proposed, and when they are, rule of thumb procedures are utilized.

Need, Effects and Feasibility of Change of Mode

"There is a need for improved speed and fluidity of traffic movement in urban central business districts and along dense corridors of travel, including relief of traffic congestion and reduction in the demand for downtown parking space, attraction of riders to transit services, and reduction in travel time and costs" (14). As early as

1948, Hughes argued that "...a large number of automobiles the owners of which are destined for downtown, must be stopped..." He is of the opinion that "Fringe parking does seem to hold promise as an important factor in remedying traffic congestion on downtown streets" (1). Heineman is quoted as saying "without adequate parking, low cost suburban rail service cannot continue to grow" (15).

The argument in favor of change of mode is summarized by Schulman (16). He says that "When situations arise in which demands exceed the physical capacity of the area to provide parking, some program of coordination must be developed among the roadway system, the parking program, and the transit system. It is this type of coordinated program that provides the basis for an adequately designed transportation system."

Deen, based on the first survey of change of mode says that

> "When utilized, fringe parking benefits the urban community since it capitalizes on the best features of both auto and transit modes. The flexibility in time and space of the auto is used in outlying areas when transit service is uneconomical. The higher capacity capabilities of transit are harnessed in the closer-in parts of the city where auto capacity is limited".

Summarizing the benefits of change of mode parking facilities,

"1. Automobiles are taken off the road in and near the central city area

2. Cars are taken off the road during the peak traffi- hours

3. The addition of new passengers strengthens transit service and allows increased frequency of service
4. Downtown parking problems are eased... The reduction in demand for downtown parking...[and] more space is then available for primary land uses..." (17).

It is reported, as a result of a demonstration project in the Tri-State region, that "a Park 'N Ride station that has convenient vehicular access with ample parking space will attract new patrons to rail service" (9). Milwaukee reports that "passengers are willing to change mode...from an automobile to a bus in commuting to downtown" (18). It is also reported that "based on twelve years of experience, the Cleveland rapid transit operation has clearly demonstrated that there is a widespread demand for extensive 'change of mode' facilities in the form of large parking lots...at outlying rapid transit stations" (19). The same report goes on to say that "we have seriously underestimated the 'hunger' for these convenient and attractive facilities by automobile users".

Findings of Change of Mode Parking Surveys

The second theme in the literature reports the results of surveys in the field of Change of Mode, and of federally subsidized demonstration projects. Boston, Cleveland, Milwaukee, Washington, Chicago, Baltimore, New York, Pittsburgh and Philadelphia are metropolitan areas where such surveys have been taken. The main findings are reported below.

It is reported that change of mode parking facilities at rail transit stations are generally utilized, with an average 81 percent occupancy (17). More recently the ITE survey indicates that average occupancy ranges from 12 to 86 percent (13). Many facilities however are reported to exceed 100 percent occupancy. The experience of the Skokie Swift parking lot, in the Chicago area, indicates that one third of the change of mode passengers parked on the curb because the lot was full (10).

Turn-over rates have been investigated as in Cleveland where a survey indicated that a parking stall is used at the rate of 1.3 cars per day (19). Boston found a 1.1 turn-over rate (4).

In Cleveland, car occupancy of change of mode vehicles was found to be 1.2 passengers (19). In Washington, on the average, each parked vehicle approximately carried 1.1 persons (17). Variation in turn-over rates and car occupancy is due to the proportional distribution of change of mode users between Park and Ride, and Kiss and Ride. In Washington, about 85 percent of all persons using the lots came in a car that was parked on the site (17) while Cleveland's experience shows this percentage drops to around 65 (19).

Arrival rates at the change of mode lots are by far the highest during the morning rush period. As part of a demonstration project, counts by trainmen showed that the four morning trains were accounting for 77 percent of the downtown weekday patronage (9). Washington's experience is similar.

The mode of travel prior to the establishment of change of mode parking is important in computing the total savings that accrue to a community. Cost savings are due to only those that are diverted from using their auto all the way to the CBD. Washington reports, as a result of a survey, that twenty-five percent of the respondents formerly drove all the way to their destination. If this proportion is representative, it would imply that for every four parked vehicles in a fringe lot, one car is removed from the traffic stream (17). This proportion also implies that the savings to a community should be computed for only twenty-five percent of the parked cars. The ITE survey indicates that the proportion of diverted users is one to five (13).

Cleveland, Boston and Milwaukee report on the origin of change of mode parkers. Boston, as an example found that some parkers live a considerable distance from the lots they use. 25.5 percent live seven to 15 miles away and 7.3 percent travel between 15 and 20 miles (20). Experience in Milwaukee indicates that origins of parkers are less spread out.

All instances of change of mode confirm the fact that the phenomenum is basically associated with work trips. In Washington, about 96 percent of those who reported the purpose of their change of mode trip were persons going to work (17). Milwaukee, reports that home to work and home to school, and reverse, are almost the only trip purposes (18). Similarly in Boston one finds that 98.2 percent of the parkers have a work trip purpose and 96.7 percent make the return trip by transit (20). Also, most users are regular users. Nearly three quarters of the change of mode parkers use the lots five days a week (20).

The experience with change of mode parking lots is varied. Many facilities have attracted a large number of users, and some have been financially solvent. However, it is important to note that many change of mode facilities have failed. The most important reason for such failure is that the desires of the users were not provided (21).

The literature reveals that there exists three main reasons responsible for diverting auto trips into change of mode, with one necessary condition being a competitive transit service. "Avoidance of downtown parking costs is the main motivation of fringe parkers in the Washington area" (17). In many cases downtown parking cost is a large portion of the out-of-pocket trip cost. Parkers desire to reduce out-of-pocket costs.

"The facts that using rapid transit is more comfortable and convenient, and eliminates bucking daily traffic were the advantages most cited (52.6%) by respondents [change of mode parkers] when asked to compare the advantages of rapid transit over automobile commuting" (20). Comfort and convenience imply that the change of mode service and lot be reliable, flexible and easily accessible (22).

The last reason given becomes evident when one considers that a quarter of the users "...indicated that they liked parking in a fringe lot because they did not like to park on the street..." (17). Safety and physical quality of the parking lot are the implications.

Factors and Criteria Affecting Change of Mode Parking Demand

The last theme is discussed next in the change of mode literature. An existing example of good physical design for change of mode facilities is provided by Cleveland. Parking aisles are lined perpendicular to the transit tracks. Collapsable posts are used to delineate drives and pedestrian sidewalks which are raised six inches above the pavement. Incandescent floodlights are used for parking lot lighting. A raised concrete platform is provided for kiss & ride auto passengers. The sawtooth loading platform is used to provide a more flexible bus operation (19).

The BART study outlines the elements of the geometric design of change of mode facilities.

> "Optimally, parking and circulation facilities should be grouped around the long narrow station, (a) to provide the closest access to the train platforms for the most efficient access modes to encourage use of these modes, (b) to minimize walking distances between train platforms and all parking stalls, (c) to optimize the number of vehicular entrances from and exits to the street-highway network, and (d) to optimize automobile, taxi, and feeder transit loading, unloading, ingress and egress" (23); (See Figure 1).

As far as the factors that affect the demand for change of mode parking, one should look at the reasons behind the choice that commuters make. The availability of a place to park, the provision of off peak service, the existance of feeder transit, the presence of a good distribution network in the downtown combine to provide a reliable and flexible facility, and hence a convenient service. The convenience of the service is what users want. Comfort, being another reason for the diversion of auto trips into change of mode, dictates adequate transit scheduling, good facility geometric and physical designs, and the provision of shelters while waiting for transit. High downtown parking costs and the existance of vehicular congestion in arterials force commuters to change mode. Both factors tend to increase with metropolitan area size.

The feasibility study of change of mode in the Washington area adds several other factors that affect lot usage (6). Distance from lot to downtown, competition

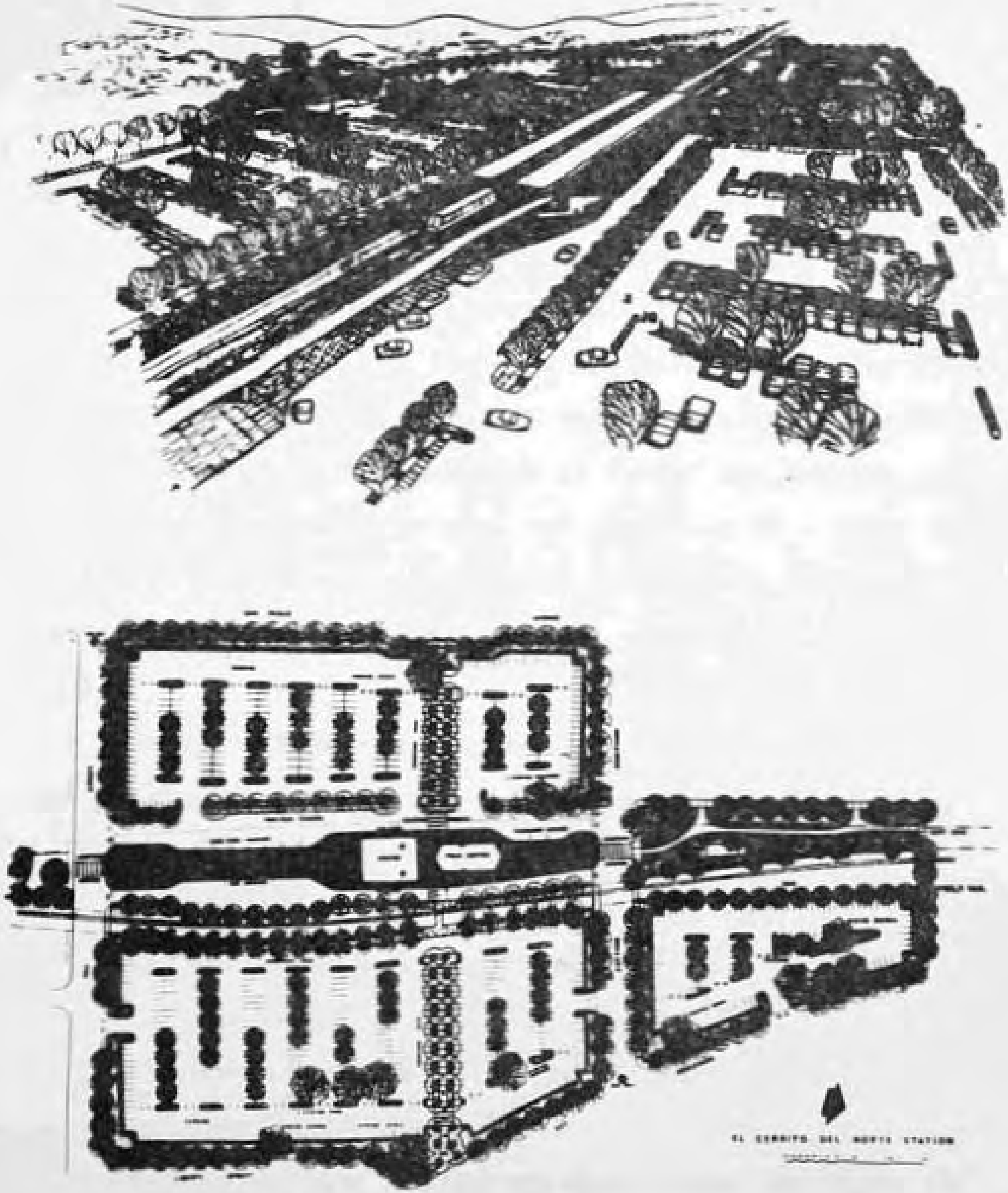

FIGURE I PROPOSED CHANGE OF MODE PARKING LOT, BART SYSTEM (24) with existing lots, and relation to fare zone boundary are used. The ITE survey reports that shorter transit headways, and faster rapid transit as compared to bus service increase the change of mode lot usage (13).

Both Boston and Washington confirm that in general, cost of parking at the change of mode lot is a very sensitive factor in determining lot usage (17).

Let us now review the proposed criteria for successful change of mode that are found in the literature. The fringe lot must offer something better than is available on the street if it is to be used such as better bus service, a safer place to leave the car, the assurance of a place to park, and a shelter while waiting for transit (17). Facilities constructed must also be aesthetically pleasing (15).

The city of Boston proposes the following criteria for parking fees at change of mode lots:

(a) where occupancy is 85 percent or more, raise the fee;

(b) where occupancy is 74 percent or less, lower the fee;

(c) where occupancy is 75 to 84 percent do not change the fee (4).

To conclude this chapter we will review the state of the art as far as the prediction of change of mode demand is concerned. The ITE survey, reports that patronage estimates were developed for the BART system using what are essentially conventional estimating techniques (13). The total number of transit trips are estimated using modal split curves based on the speed ratio of transit to auto. Later, transit trips are broken down by mode of arrival to the transit station. Finally the size of the parking facility is estimated by dividing the number of transit trips that arrive by car by an estimated average car occupancy. The Shirley Highway change of mode parking demand has been determined in the same fashion (12). A study of terminal transfer facilities concludes that "under most interchange traffic patterns the upper limit [of change of mode parking demand] would be in the range of 1200 to 1600 spaces" (25). A more recent study of parking at interchanges similarly concludes that "The demand for transit-oriented parking at suburban interchanges may range from 10 to 20 spaces to as many as 400 to 500 spaces where express bus service is offered and 1,000 to 1,500 spaces where commuter rail rapid transit is available" (26).

CHAPTER 3: CHANGE OF MODE DATA

The literature review, as reported in the previous chapter, has furnished (a) the ability to locate some of the instances of change of mode, (b) names of responsible agencies, (c) insights into data collection needs, and (d) available data.

Data Collection

Data collection depends on the financial constraints of the research project, the magnitude of data needs, and the location of facilities which are to be investigated. However, data collection should allow for the systematic fulfillment of the research objectives.

Sample Design

The object of experimental design is to determine which of the experimental units are to be observed, how the observations are to be made, and what is to be observed. What is to be observed is closely associated with the objectives and methodology of the research project, which have been previously stated. Data are to measure the demand for and characteristics of change of mode parking facilities. The data format might also allow for an analysis of variance and a regression analysis to be performed.

Two factors influenced the selection of the data collection method. The first was the financial constraint of a quite limited budget. Secondly the extensive geographic distribution would have placed a strain on all but a most lucrative budget. Therefore, it was necessary to rely on data already collected or easily provided by change of mode operators. On the basis of the above, it was decided that a questionnaire should be sent to change of mode operators. The literature was used as a starting point to solve the problem of where to send the questionnaires. A preliminary study was performed to find additional names and addresses of change of mode operating agencies, and of the responsible personnel. Correspondence was started with the change of mode operators, in order to elict as much of the pertinent information as feasible. With the fine cooperation of the operators, it was possible to devise an extensive and feasible questionnaire.

The third and last part of the experimental design was to select the facilities to be investigated from among those which fall within the scope of the project. Successful and unsuccessful facilities must be polled so as not to bias the statistical analyses. In order to make sure that there exists an adequate variation within all proposed independent variables, it was decided to include all known facilities. Many of the change of mode parking facilities have been in use for a long period of time. During this time, many of the characteristics and the demands have radically changed. For this reason it was decided, wherever feasible and warranted, to make observations at different points in time.

Questionnaire

Now is the time to discuss in detail the data items that are needed to achieve the objectives of the project. The change of mode demand and a variation therefrom are the independent variables used in the regression and variance analyses respectively. Therefore, the first part of the questionnaire is concerned with measuring the demand placed upon change of mode facilities. The questionnaire is found in Appendix A. The measurement of change of mode demand includes the determination of the number of park 'n ride vehicles, kiss 'n ride vehicles, and change of mode passengers that use the parking facility per day. An average weekday demand is sought. Variations which occur in the demand include yearly, daily and peak hour versus non peak. Overflow of parking lots takes place, and a knowledge of the extent of this overflow is needed to determine the actual demand for change of mode.

The demand for change of mode parking depends upon the characteristics of the transit serving the facility, such as the type of transit, headways, fares, travel times and the adequacy of the distribution network at the downtown end of the trip.

The third part of the questionnaire concerns itself with measuring the physical characteristics of the parking lot. The adequacy of lighting, egress and ingress, delineation, and pavement condition are considered to be measures of the physical characteristics. The quality of the transit terminal and the walking distance from parked car to transit platform are also necessary measures.

The operational characteristics were to be provided by the fourth part of the questionnaire. Respondents were asked to reply to querries regarding the presence and magnitude of kiss 'n ride stalls, feeder bus berths, and attendants. They were also asked questions concerning the extent of the parking service, such as the number of hours within a day and the number of days within a week. The size of the facility, the parking fee charged, and the quality of maintenance were measured.

Part five of the questionnaire measured the location of the change of mode facilities within the metropolitan area. The type of surrounding land use, the distance to downtown and the location with respect to competitive facilities and transit fare zones were among the requested information. The proximity to, the visibility from, and the type of highway access were also considered to be relevant measures of location.

The last part of the questionnaire attempted to measure the metropolitan area characteristics that affect the demand for change of mode. The flexibility and speed of the transit system, and the level of radial travel congestion and downtown parking are such characteristics.

Results of Survey

When using the results of this research, one should keep in mind that a large portion of the information requested in the questionnaire required subjective responses. Because some of the respondents were providing information on several facilities, every effort was made to pre-answer as many questions as possible. A record was kept of all such answers, and a code number was given to each questionnaire in order to keep track of the record.

Response to Survey

A total of 357 questionnaires were mailed to sixty different agencies in twelve metropolitan areas. Information was requested for 134 facilities at which the transfer is to rail, and for 36 facilities at which the transfer is to bus transit. A total of 26 agencies replied, and gave information concerning 73 rail change of mode facilities plus 20 bus facilities. As a result of the survey, 190 usable observations are made.

Table 1 presents the response to the survey, and gives the number of observations desired and obtained,

TABLE 1. SUMMARY OF RESPONSE TO SURVEY

Metro-politan Area	Mailed Question-naires		Unreturned Question-naires		Returned Question-naires		Unusable Question-naires		Usable Question-naires	
	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail
Milwaukee	13	--	--	--	13	--	--	--	13	--
Baltimore	3	--	--	--	3	--	--	--	3	--
Washington	35	--	--	--	35	--	21	--	14	--
New York	2	59	--	23	2	36	--	32	2	4
Chicago	2	99	2	54	--	45	--	12	--	33
Pittsburgh	--	5	--	--	--	5	--	--	--	5
Cleveland	4	44	2	--	2	44	2	--	--	44
Miami	6	--	6	--	--	--	--	--	--	--
Boston	6	57	--	--	6	57	1	2	5	55
Philadelphia	--	14	--	8	--	6	--	--	--	6
Toronto	--	6	--	--	--	6	--	--	--	6
Newark	2	--	2	--	--	--	--	--	--	--
Total	73	284	12	85	61	199	24	46	37	153

TABLE 2. PERCENT BREAKDOWN OF RESPONSE TO SURVEY QUESTIONNAIRES

	Bus	Rail
Usable	50.8	53.9
Unusable	32.8	16.2
Unreturned	16.4	29.9
Total	100.0	100.0

TABLE 3. NUMBER OF QUESTIONNAIRES PER CHANGE OF MODE FACILITY

	Mailed	Usable
Bus	2.03	1.81
Rail	2.12	2.09
Average	2.10	2.03

by metropolitan area and type of transit. Table 2 gives a breakdown of the survey by usability of the response, and Table 3 gives the average number of observations per facility.

Survey Findings

Since one of the major objectives of the research project is the analysis of the factors that affect the demand for change of mode, it is important to show the diversity that is found in the characteristics of the surveyed facilities.

The density function of change of mode parking lot size is given in Figure 2. The average facility size of the sample is 354 stalls, and the standard deviation is 396. Figure 3 presents the distribution function of percent usage for change of mode parking lots. Parking lot percent usage is defined as one hundred times the average daily number of parked vehicles divided by the facility size. The usable response of 190 observations indicates an average 92 percent lot usage with a standard deviation of 40.

Figures 4 and 5 give the density functions of the overall transit speed and transit fare respectively. Both figures demonstrate the variation in the quality of the transit service that is being transferred to at the change of mode lots. The overall transit speed includes the waiting time at the change of mode lot and the transit fare is the out-of-pocket cost exclusive of parking fees, if any.

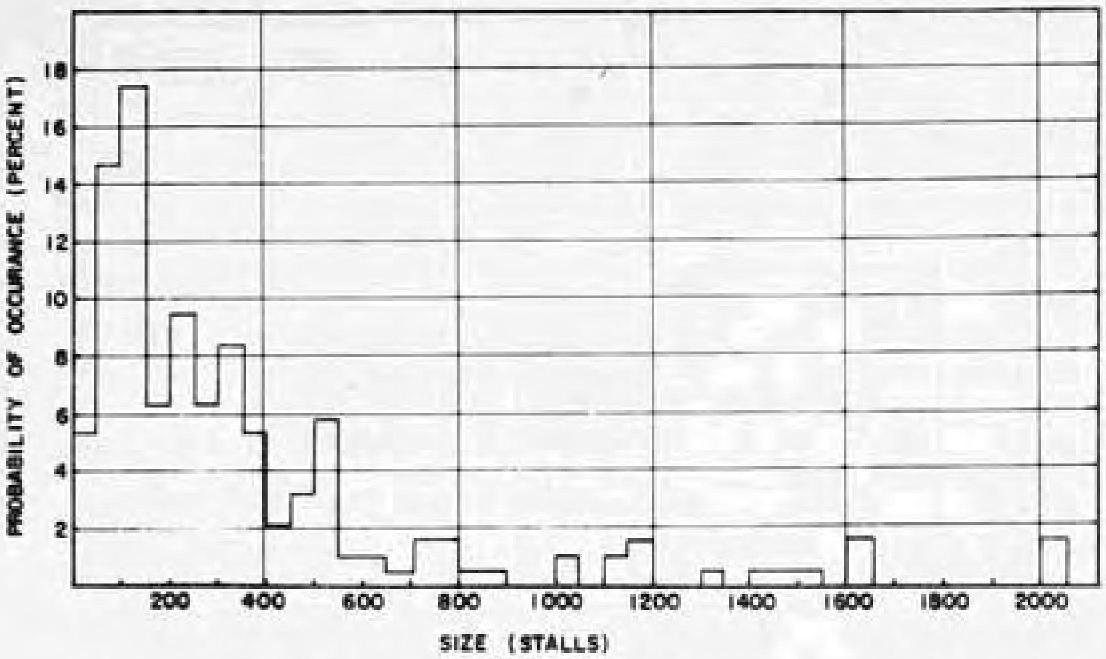

FIGURE 2 VARIATION IN SIZE OF CHANGE OF MODE PARKING LOTS

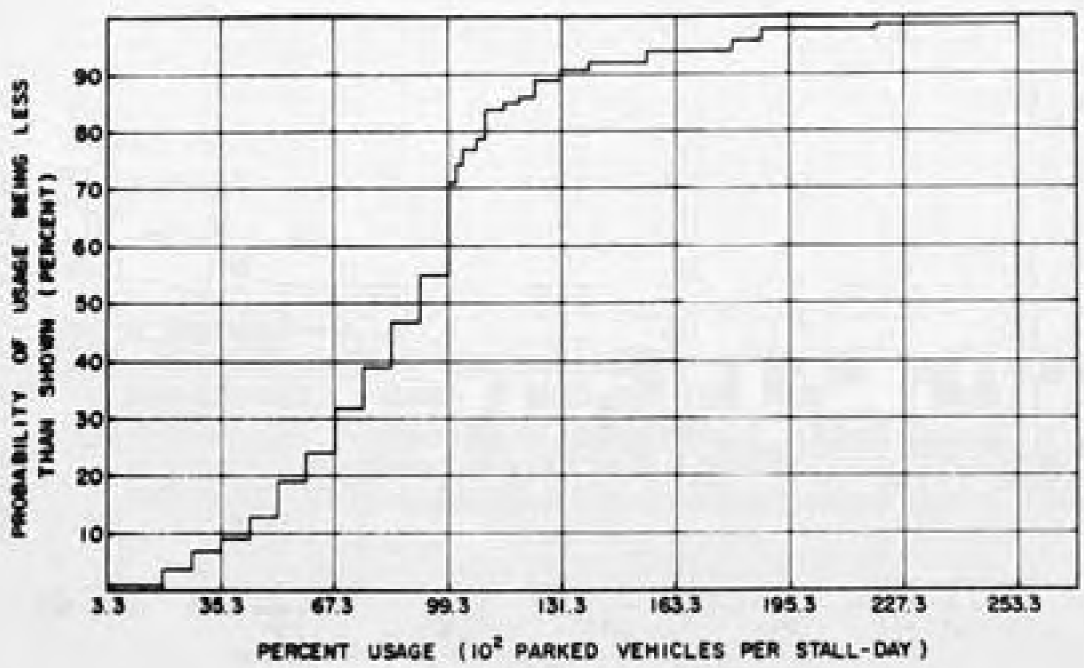

FIGURE 3 VARIATION IN PERCENT USAGE OF CHANGE OF MODE PARKING LOTS

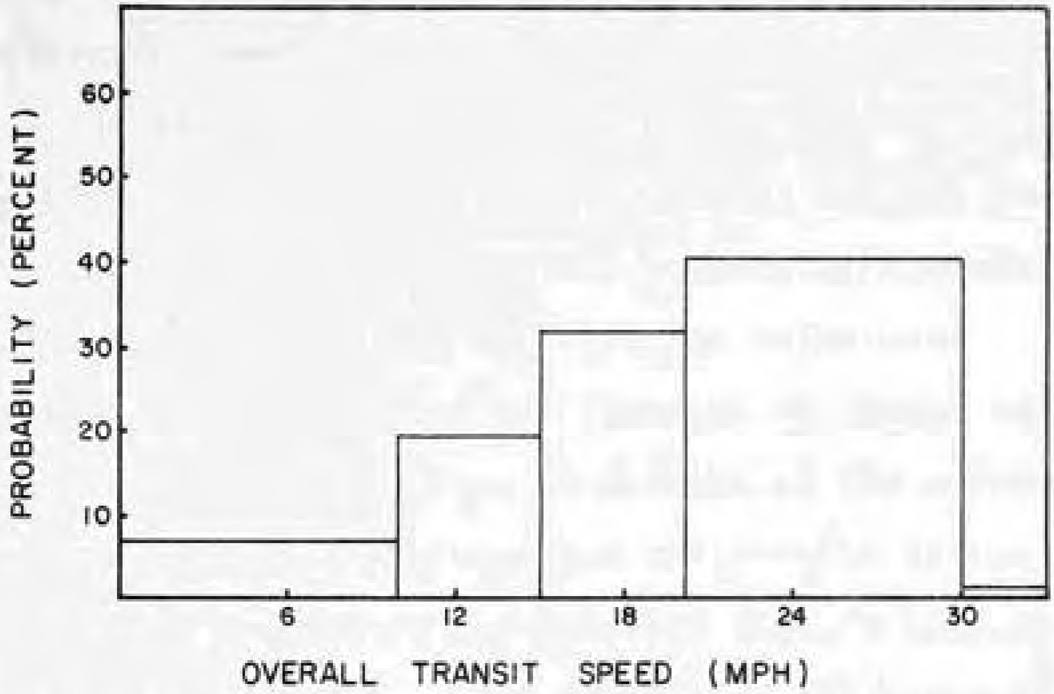

FIGURE 4 VARIATION IN OVERALL TRANSIT SPEED, FOR CHANGE OF MODE

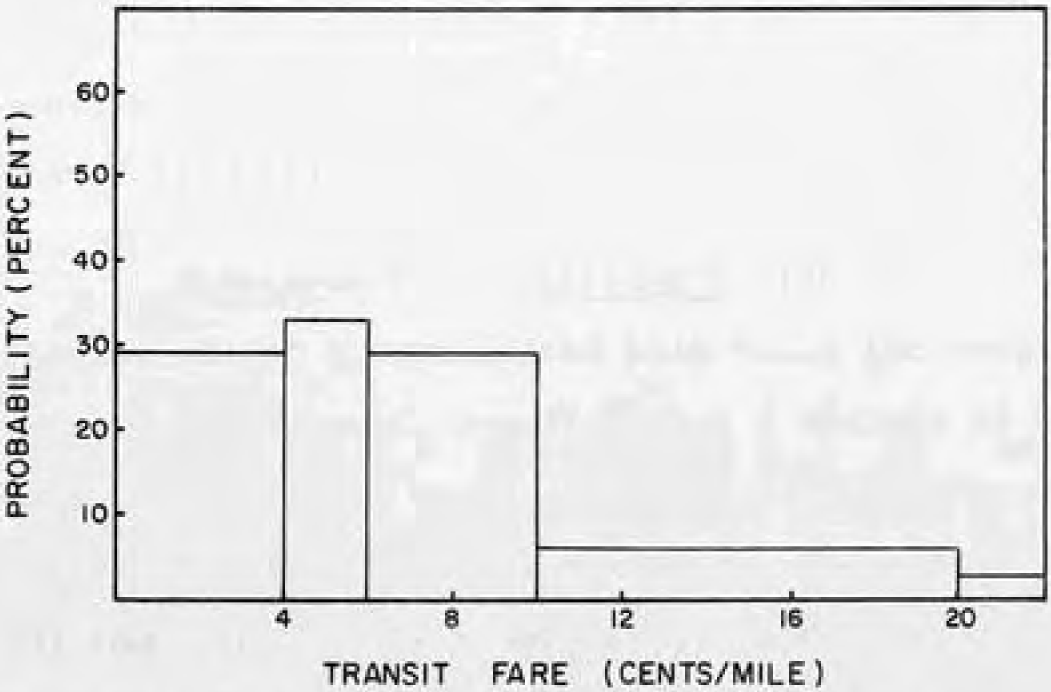

FIGURE 5 VARIATION IN TRANSIT FARE, FOR CHANGE OF MODE

Figures 6 through 9 are a pictorial representation of the diversity found in change of mode parking lot characteristics. Of the facilities polled, (a) 44 percent do not charge any parking fee, (b) only 7 percent did not have any lot enclosures, (c) 85 percent did not employ attendants, and (d) only 8 percent did not have any lighting.

Figures 10 and 11 give the location of change of mode parking lots. One finds that 46 percent of the observations are related to facilities that are not visible to the commuter, when driving on the arterial that is used as the major access to the lot. Most facilities (84 percent) are located either in commercial or residential areas or a combination of both. Finally, Figure 12 gives the distribution function of change of mode lot distances to the downtown area they serve. Most facilities (66 percent) are located from four to twelve miles from the downtown area.

Development of Aggregate Variables

The purpose of the collected data being the analysis of change of mode demand, requires that a minimum of variables be used so as to maximize the significance and reliability of the statistical analysis. Therefore, the need for combining the many data items into more representative and comprehensive variables is evident.

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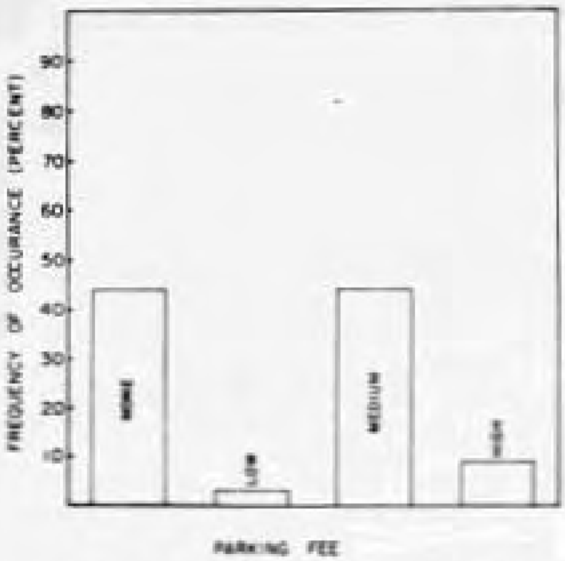

FIGURE 6 FREQUENCY OF PARKING FEE AT CHANGE OF MODE LOTS

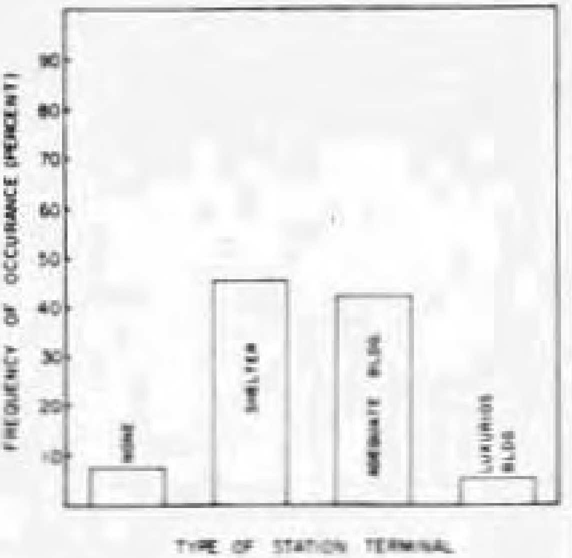

FIGURE 7 FREQUENCY OF TYPE OF STATION TERMINAL AT CHANGE OF MODE PARKING LOTS

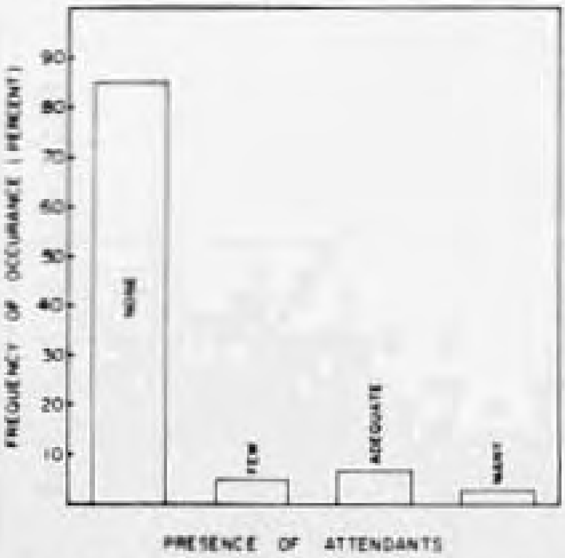

FIGURE 8 FREQUENEY OF PRESENCE OF ATTENDANTS AT CHANGE OF MODE PARKING LOTS

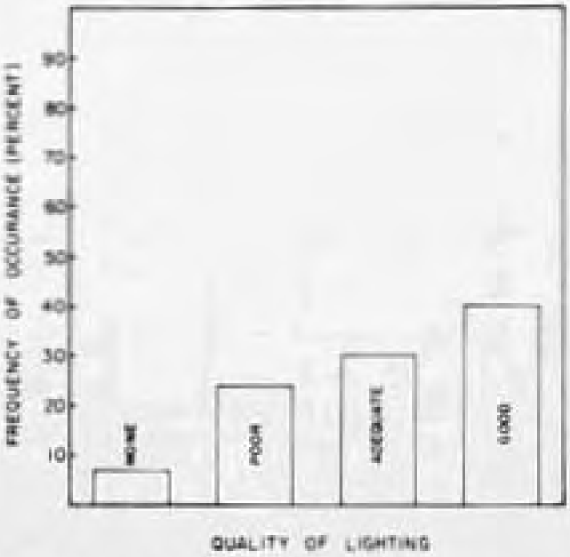

FIGURE 9 FREQUENCY OF LIGHTING QUALITY AT CHANGE OF MODE PARKING LOTS

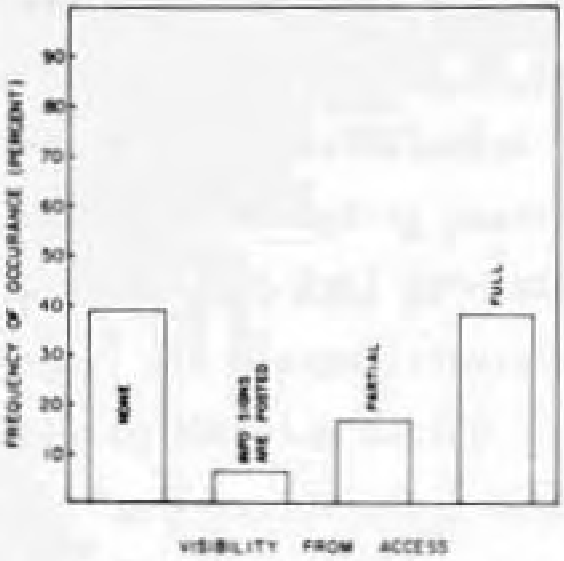

FIGURE 10 FREQUENCY OF VISIBILITY FROM ACCESS OF CHANGE OF MODE PARKING LOTS

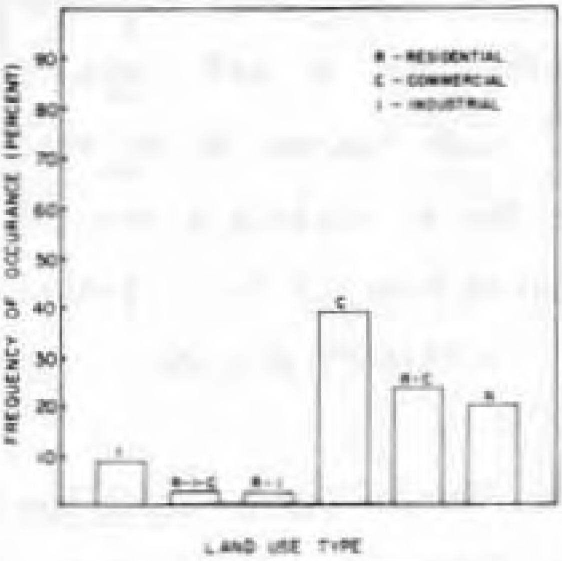

FIGURE 11 FREQUENCY OF LAND USE TYPE SURROUNDING CHANGE OF MODE LOTS

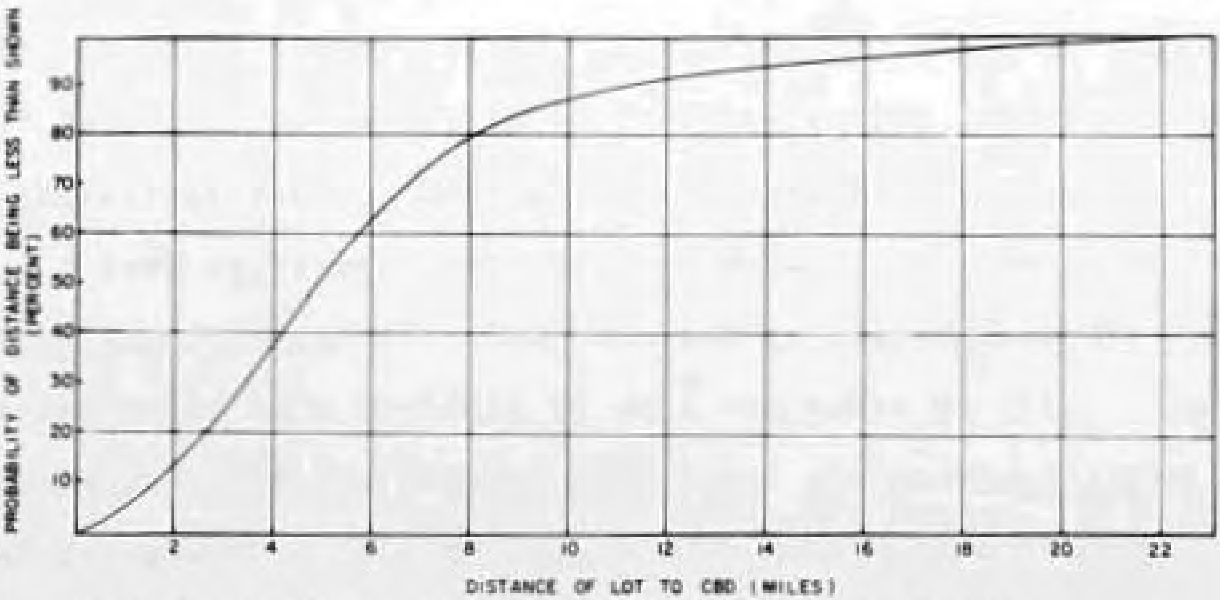

FIGURE 12 VARIATION IN DISTANCE OF CHANGE OF MODE LOTS TO CBD

Basic Concepts

Two classes of aggregate variables are developed. The first type comprises all data items that are independent of the characteristics of parking lots. The variables thus constituted are considered to behave as parameters when parking lot demand is predicted. Three aggregate variables are created to fall into this category: (a) Transit Service rating, (b) Metropolitan Area rating, and (c) Parking Facility location rating.

The variables that measure the parking lot characteristics make up the second class. Successful change of mode design criteria are developed by finding those values of this class which optimize the savings that accrue to the community. Five such variables which were developed are (a) Facility Safety rating, (b) rating for Physical Quality of Facility, (c) Facility Reliability rating, (d) Facility Flexibility rating, and (e) Facility Parking Fee rating.

Each aggregate variable is made up of a combination of data items (factors). Once an item is included in the formulation of a variable it does not enter in the formulation of any other. Data items are combined in an additive manner or a multiplicative manner or a combination of both. The decision to add or to multiply the effect of different factors is intuitively based on the manner in which a commuter would combine the factors in the process of choosing change of mode over passenger car.

To each of the factors that make up a given aggregate variable is attached an average rate that measures its relative influence in the decision making process of a commuter trying to choose between change of mode and passenger car. It is worth noting, at this stage, that there is no need to worry about the relative importance of variables, since an additive regression model is to be developed.

A set of discrete levels are formulated in order to measure the variation within factors. For each factor, a different rate is attached to each of its levels. For any given factor, the rates of its levels vary around its previously assigned average relative rate.

In this manner many qualitative (discrete) and quantitative (continuous) factors are combined in order to create a smaller number of mainly integer valued variables. It should be noted that the whole process of rating the different factors and their levels, and of combining factors is based on subjective engineering judgement. This judgement is based on an exhaustive evaluation of the previous literature in the field of modal split, and from a study of commuter decision making considerations.

In the case of a variable that measures some of the characteristics of a parking facility, it is necessary to be able to obtain a unique solution for those parking lot characteristics once a value is assigned to that aggregate variable. If an economically optimal set of values for all such variables is found, then it would be possible to determine all the associated parking lot characteristics. The lot characteristics thus determined are the design criteria for which we are searching.

Sample Development - Transit Service

The reason for this choice is that the transit service rating was found to be significant in both the analysis of variance and the regression analysis. Also, this aggregate variable involves the combination of factors by both addition and multiplication, and comprises discrete and continuous factors.

The transit service rating is made up of the following factors: (a) quality of station terminal building, (b) transit fare to the downtown, (c) overall corridor travel speed of transit, (d) proportion of downtown jobs easily reached by the transit being transferred to, (e) availability and cost of transfer within transit system, (f) number of transit fare zones, and (g) ticket marketing and collection methods.

Factors (e) through (g) are a measure of the flexibility of the transit system available at the change of mode parking facility. A commuter will define flexibility as the addition of these four factors.

The transit service rating is given by equation 1:

(1) Transit Service Rating = (station terminal bldg + Transit fare) + (transit speed x transit flexibility)

The above equation implies the following:

a. The effects of transit speed and flexibility are multiplicative as far as the commuter is concerned.

b. The commuter sense of aesthetics (quality of terminal), his cost considerations (out-of-pocket transit fare), and his comfort and convenience (transit speed and flexibility) are additive.

The seven factors that combine to describe the transit service are each subdivided into discrete levels. A rate is assigned to portray the influence of every level in the commuter's decision making process. These levels and their associated rates, which are given in Table 4, require the following remarks:

1. The average rates for quality of terminal, for transit fare, and for transit flexibility (sum of the last four factors) are all equal to four. This fact implies that the three factors have an equal influence on choice of mode. An increase in the level of a factor is offset by a comparable decrease in the level of another if the transit service rating is to remain constant.

2. The average rate for transit speed is equal to twelve and to the sum of the average rates of all other factors. Modal split models have all recognized the importance of speed, and the above stated rate assignment is the way this importance has been taken into account. The

TABLE 4. TRANSIT SERVICE RATING*

Quality of Transit Station Terminal		Transit Fare to CBD		Transit Over All Speed	
Levels	Rate	Levels (¢/mile)	Rate	Levels (mph)	Rate
Transportation Center with extra services	10	4 & below	5	30 & above	24
Luxurious	7	$4<f\leq 6$	4	$20\leq s<30$	15
Adequate	4	$6<f\leq 10$	3	$15\leq s<20$	9
Shelter	2	$10<f\leq 20$	2	$10\leq s<15$	6
None	1	Above 20	1	Below 10	3

Proportion of CBD Jobs Reached by Transit		Availability and Cost of Transfers Within Transit		Transit Fare Zones (More Than One)		Ticket Marketing and Collection Methods	
Levels	Rate	Levels	Rate	Levels	Rate	Level	Rate
High	4	Available, 10¢ and less	1	Yes	1	Innovative	2
Average	2	Not available, or available & more than 10¢	0	No	0	Good	1
Low	1					Adequate	0

*Transit Service rating = (station terminal bldg + Transit fare) + (Transit Speed x Transit flexibility) implication of such rate assignments is that transit speed is as important to the commuter as the sum of all other factors. In other words, a decrease in the transit speed level if accompanied by a comparable increase in the level of all other factors will not change the decision of a commuter choosing between change of mode and passenger car, since the transit service rating would be unchanged.

3. The transit service improves with (a) an increase in the quality of the station terminal, (b) a decrease in the transit fare, (c) an increase in overall transit travel speed, (d) an increase in the proportion of CBD jobs easily reached by transit, (e) the availability of low cost transfers, (f) the existence of more than one fare zone, and (g) an increase in the quality of ticket marketing and collection methods.

As an example, a transit service rating is computed for a change of mode parking facility:

1. An adequate transit station terminal at the change of mode lot.
2. A transit fare of forty cents (the station is six miles from the central business district). The fare is therefore 6.67 cents/mile.

3. A transit travel time from station to downtown of 16 minutes, with a peak headway of 5 minutes. The overall travel speed is thus 19.5 miles/hour.
4. The transit distribution network in the downtown area easily reaches a low proportion of jobs.
5. Transfers are not available within the transit system.
6. The transit system has two fare zones.
7. The transit system possesses good ticket marketing and collection methods.

Using Table 4, one reads the following rates: 4,3,9, 1,0,1,1. Combining these rates according to equation 1, we get:

Transit Service rating = 4+3+9x(1+0+1+1) = 34

Seven factors were combined to obtain an integer valued variable which will be used to predict change of mode parking demand. The reader is referred to Appendix B for the methods used in developing the remaining aggregate variables (i.e.: the factors involved in each variable, the levels and associated rates for each factor, and the equations used to combine factors into aggregate variables). Table 5 summarizes the results of the modeling technique. The complete results of the modeling process are tabulated and given in Appendix C.

TABLE 5. DATA SUMMARY OF AGGREGATE VARIABLES

Variable	Theoretical Range		Sample Range		Sample Average	
	Min.	Max.	Min.	Max.	ANOVA	Regression
Transit Service	5	212	14	99	48.30	48.32
Metropolitan Area	6	32	14	30	22.78	21.61
Facility Location	0	88	6	64	33.83	34.21
Facility Safety	0	6	1	6	4.03	3.74
Physical Quality of Facility	3	12	6	10	8.92	9.22
Facility Flexibility	0.0	22.0	0.0	18.0	5.23	6.48
Facility Reliability	0.8	19.0	3.0	17.0	6.61	5.85
Facility Parking Fee	1	6	2	6	4.28	4.40

CHAPTER 4: PARKING LOT USAGE

This chapter reports on the procedure employed and the findings of the analysis of variance, regarding the effect of the aggregate variables (see Chapter 3) on change of mode parking lot usage. The analysis of variance is based on 190 observations made over 93 facilities in ten different metropolitan areas.

Procedure of Analysis

The object of the statistical analysis is to study the trends and significance of the effects of the parametric and design variables on the percent usage of change of mode parking lots. It should be understood that the percent usage of a lot measures the success of a lot in attracting change of mode parkers.

Two-Way Classifications

There are eight independent variables to be studied. The limited number of observations, and the impossibility of controlling the values of the independent variables did not allow for a simultaneous study of the effects of all variables. To study the effect of one variable at a time is misleading, due to the intercorrelation between independent variables. It was therefore decided to form all possible two-way classifications (28 in total), thus, the effect of each independent variable is studied in conjunction with the remaining seven, each one at a time. This repeated two-way classification analysis technique allowed us to study the main effects as well as the interactions between variables.

As an example, the physical quality rating by the transit service rating as a two-way classification was considered. The physical quality rating of a change of mode lot was subdivided into six groups: 3 to 5, 6, 7, 8, 9, 10 to 12. The transit service rating was similarly divided into nine groups: 5 to 19, 20 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69, 70 to 79, 80 to 89, 90 to 212. A two-way classification table with six columns and nine rows was formed. The columns are defined by the physical quality groups, and the rows are defined by the transit service groups. The 190 observations were then placed in the 54 cells of the table, depending on their physical quality and transit ratings. The percent usage of an observation is the value that is entered in the table.

Many cells were found to be void of observations. It is necessary to have at least one observation per cell in order to run an analysis of variance for the two ratings under consideration. It was therefore decided to reduce the number of columns and rows in the two-way table so as to form larger cells, and hence satisfy the constraint. As a result we obtained a table with three columns and four rows, and thus twelve cells. For the sample two-way classification used, Table 6 gives the number of observations per cell, and Table 7 gives the cell means and variances.

Twenty-seven additional two-way classifications were formed following the same method as that explained above. Before assessing the significance of the eight ratings upon parking lot usage one must ascertain that the data satisfy the statistical assumptions inherent in the analysis of variance.

Statistical Constraints

The two-way classification model is given by equation 2:

$$(2)\quad U_{ijk} = \mu + T_i + Q_j + (TQ)_{ij} + \varepsilon_{ijk}$$

where

U_{ijk} = percent usage of the kth observation in cell (i, j)

μ = true mean effect

T_i = true effect of the ith level of the transit service rating (T)

Q_j = true effect of the jth level of the physical quality rating (Q)

$(TQ)_{ij}$ = true effect of interactions between factors T and Q for the (ij)th treatment combination

ε_{ijk} = true effect of the kth observation subjected to the ith level of factor T and to the jth level of factor Q.

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TABLE 6. NUMBER OF OBSERVATIONS PER CELL, FOR SAMPLE TWO-WAY CLASSIFICATION

Observations Per Call		Physical Quality Rating 10-12	7-9	3-6
Transit Service Rating	60-212	19	27	4
	40-59	16	28	2
	30-39	36	24	6
	5-29	15	11	2

TABLE 7. OBSERVATION (PERCENT USAGE) MEANS AND VARIANCES, FOR SAMPLE TWO-WAY CLASSIFICATION

Mean / Variance		Physical Quality Rating 10-12	7-9	3-6
Transit Service Rating	60 to 212	89.7 1357	98.8 2976	142.7 1141
	40 to 59	106.0 3004	85.9 2393	112.8 325
	30 to 39	80.9 529	103.4 774	105.7 27
	5 to 29	66.9 1350	100.4 280	42.0 648

with:

$$\sum_{i=1}^{t} T_i = \sum_{j=1}^{q} Q_j = \sum_{i=1}^{t} (TQ)_{ij} = \sum_{j=1}^{q} (TQ)_{ij} = 0$$

This implies that the model is fixed (all the remaining 27 models are also fixed). There exists two assumptions regarding the error term (ε_{ijk}), and these are:

1. ε_{ijk} are normally distributed with mean equal to zero.
2. ε_{ijk} are independent of i and j (i.e., variances within cells are homogeneous).

The Bartlett test for homogeneity of variances is used to test for the above stated constraints. The two reasons for this choice are: (a) if homogeneity of variances within cells is met, then the error terms are by necessity normally distributed; (b) the number of observations within cells need not be equal.

Using the cell variances given in Table 7 one gets a χ^2 of 54.0* with 11 degrees of freedom. The critical χ^2 is equal to 33.1**. In other words the homogeneity of variances within cells is not accepted (54.0 > 33.1) even at the very slim chance of 5 in 10,000. Similar results were found for the remaining 27 two-way classifications.

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* The computations for the Bartlett χ^2 were performed at the Purdue University Computer Center, and using the library program DATASUM.

**The critical χ^2's are given in Ostle (27), pp. 524-527.

Therefore, it was found necessary to mathematically transform our independent variable (percent usage) in order to reduce the actual χ^2's and thus increase the probability that variances within the cells of a two-way classification are equal. Three transformations were tried. The percent usage was transformed into its logarithm to the base ten, its square root, and its inverse. Table 8 gives the computed Chi-squared of the Bartlett test for the percent usage and its three transformations, for all two-way classifications. It will be noted that the square root transformation provides us consistently with the lowest χ^2, and thus maximizes the probability that the two-way classifications satisfy the assumptions regarding the error term (i.e.: normality and independence).

The probability that cell variances are equal varies from one two-way classification to another. In some instances this probability is smaller than 0.0005, and in others it is as high as 0.80. The homogeneity of variance is accepted at the 0.001 level (a chance of 1 in 1000) in approximately two thirds of the cases. Similarly, this hypothesis, assumption or constraint is accepted, correct or met at the one percent level (a chance of 1 in 100) in approximately one third of the cases. An often used level at which homogeneity of variances is tested is the one percent level. This means that if there exists only one

TABLE 8. BARTLETT'S χ^2 AND THE MAXIMUM LEVEL AT WHICH HOMOGENEITY OF VARIANCE IS ACCEPTED FOR THE SQUARE ROOT TRANSFORMATION

Two-Way Classification		Chi-Squared				Acceptance α level for $\sqrt{U}$
Name*	Dimension	U+	$\log_{10}U$	1/U	$\sqrt{U}$	
TxM	4x3	91.7	107.6	460	79.6	---*+
TxL	4x4	60.9	81.0	422	52.1	---
TxS	4x4					---
TxQ	4x3	54.0	82.9	421	52.0	---
TxF	4x2	45.3	63.3	403	36.6	---
TxR	4x4	105.5	102.3	478	84.8	---
TxP	4x3	65.2	62.9	360	48.3	---
LxM	4x3	46.1	41.3	364	24.2	0.0115
SxM	4x3	50.0	49.2	380	28.7	0.0025
QxM	3x3	46.9	46.5	343	31.2	---
FxM	2x3	36.6	36.2	360	18.0	0.0033
RxM	3x3	56.9	38.6	372	26.9	0.0008
PxM	2x3	34.6	31.2	321	17.7	0.0038
SxL	4x3	22.9	38.9	362	13.3	0.2800
QxL	3x3	28.2	24.6	284	15.0	0.0625
FxL	3x4		115.1	359	108.8	---
RxL	4x4	54.0	52.1	381	32.8	0.0049
PxL	2z4	18.4	20.7	286	8.3	0.3110
SxQ	4x3	14.7	45.8	396	11.8	0.3800
SxF	4x2	33.4	52.7	381	24.7	0.0008
SxR	4x3	42.7	50.7	346	28.6	0.0025
SxP	4x2	6.5	32.2	343	3.9	0.7900
QxF	3x2	15.2	21.8	253	11.4	0.0475
QxR	3x4	42.6	42.6	390	22.2	0.0230
QxP	3x2	17.4	24.7	248	13.5	0.0190
FxR	2x4	49.0	50.6	412	29.2	---
FxP	3x3	28.7	44.3	310	25.1	0.0017
PxR	2x4	39.6	30.2	358	16.4	0.0225

*T = Transit service rating, M = Metropolitan area rating, L = Facility location rating, S = Facility safety rating, Q = Facility physical quality rating, F = Facility flexibility rating, R = Facility reliability rating, P = Parking fee rating.

+U = Parking lot percent usage.

*+Acceptance α level is smaller than 0.0005.

chance in a hundred that the statistical hypotheses of independence and normality be accepted, then the researcher is usually advised to consider the statistical constraints as being met.

The decision was taken to run the analysis of variance on the square root transformation of the percent usage (ten times the square root of parked vehicles per stall per day), since the assumptions of error normality and independence would be substantiated by the transformed data.

Analysis of Variance Results

The twenty-eight two-way classifications analysis of variance was performed at the Purdue University Computer Science Center. UNEQUAL is the name of the statistical computerized library program that was used to build the analysis of variance tables.

Statistical Significance of Ratings

The F-test was used to decide whether to accept or reject the hypothesis that the effects of a rating upon the square root of parking lot percent usage is statistically not significant. The effects of a variable include the main effects and the interaction effects. An α level of 0.1 was used to decide on the non significance hypothesis. In other words, if the hypothesis is rejected then there exists a maximum ten percent chance that the decision to reject is in error. The ten percent chance used herein is a widely accepted rate of risk.

TABLE 9. SAMPLE ANOVA TWO-WAY CLASSIFICATION TABLE

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratios	
				Computed	Critical
T Main Effects	17.89	3	5.96	1.43	2.08
Q Main Effects	21.32	2	10.66	2.55	2.30
TQ Interactions	82.18	6	13.70	3.28	1.77
Error	743.29	178	4.18		

Table 9 is a sample analysis of variance table. It shows the sum of squares, the mean squares, and degrees of freedom associated with both factors and their interactions. The computed F-ratios and the associated critical 0.1 α level F-ratios* are also given. From Table 9 it can be noted that the computed F-ratios are greater than the critical F-ratios for the main effects of the physical quality rating, and for the interactions between physical quality rating and transit service rating.The opposite is true for the main effects of the transit service rating. Therefore, the main effects of the physical quality rating and the interactions between physical quality rating and transit service rating are significant, while the main effects of the transit service rating do not significantly affect the square root of the percent usage.

Tables 10 and 11 give the results of all 28 ANOVA tables. Table 10 deals with the main effects of the ratings. The values given in both tables are the ratios of the computed F's by their associated 0.1 critical F's. Values of 1.00 and more, for this ratio between F's, imply that the computed F is equal to or larger than the critical F. Under such circumstances the hypothesis of non-significance is rejected. When the ratio between F's is smaller than one, then the hypothesis of non-significance cannot be rejected.

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*The critical F-ratios are given in Ostle (27) pp. 530-543.

TABLE 10. RATIO OF COMPUTED BY CRITICAL F, FOR MAIN EFFECTS OF RATINGS

		Variable							
		T	M	L	S	Q	F	R	P
Associated Variable	T		4.78	0.90	1.58	1.11	5.30	2.06	1.69
	M	0.33		0.56	3.26	0.74	2.13	3.78	0.22
	L	1.73	8.21		2.78	1.47	1.32	5.15	2.38
	S	0.35	2.69	0.30		2.32	2.43	4.49	1.39
	Q	0.69	3.50	0.33	5.09		2.63	6.43	1.12
	F	1.38	7.95	0.60	3.48	1.26		7.35	2.41
	R	1.06	3.99	0.18	1.12	0.63	0.78		0.14
	P	1.43	2.28	0.41	3.16	0.79	2.32	4.27	

TABLE 11. RATIO OF COMPUTED BY CRITICAL F, FOR INTERACTIONS BETWEEN RATINGS

		First Variable							
		T	M	L	S	Q	F	R	P
Second Variable	T		1.47	1.58	0.87	1.85	0.66	1.46	1.95
	M	1.47		0.79	1.41	0.65	0.01	0.93	1.80
	L	1.58	0.79		1.07	1.10	1.35	0.98	0.11
	S	0.87	1.41	1.07		2.79	0.49	0.99	2.36
	Q	1.85	0.65	1.10	2.79		0.03	0.71	0.59
	F	0.66	0.01	1.35	0.49	0.03		1.68	1.88
	R	1.46	0.93	0.98	0.99	0.71	1.68		0.99
	P	1.95	1.80	0.11	2.36	0.59	1.88	0.99	

As a result of the analysis of variance the following conclusions are taken (refer to Tables 10 and 11):

1. The main effects of the metropolitan area rating are significant in all of the seven cases in which they appear. The same applies in the case of the facility safety and the facility reliability ratings. The three above mentioned ratings are factors that do affect the usage of change of mode parking lots.
2. The main effects of the facility location rating are found to be always not significant. Four possible reasons could explain this finding. First, the modeling of the location rating could be inadequate; or second, the location rating interacts to a high degree with other factors; or third, the location rating truly does not affect the usage of parking facilities; or, finally and most likely, a high percentage of the transit facilities reporting had very good locational characteristics, which provides low variation in the location rating. Variables with low variation are generally found non significant.
3. The main effects of the remaining ratings (transit service, physical quality, flexibility, parking fee) are found to be significant in more than half of the cases in which they are involved. The data seems to suggest that the four factors significantly affect the usage of change of mode parking facilities.

4. Most of the interaction terms that contain the transit service rating, the location rating or the parking fee rating are found to significantly affect the percent usage of parking facilities. These findings seem to indicate that the extent to which a facility is used is based on combining the three mentioned factors with the design ratings (safety, quality, flexibility, reliability).
5. The large number of effects that were found to be significant indicates that the change of mode phenomenum is quite complicated. The fact that most main effects are significant tends to give credence to the modeling technique that was used to develop the ratings.

Trends of Ratings' Effects

Now that we have seen which variables affect the usage of a facility, the question is to show how these variables affect the occupancy of change of mode lots. For this purpose, cell means of the two-way classification tables were plotted. Figures 13a through 13h are eight such plots that are chosen to show the trends of the ratings' effects on change of mode lot usage.

It should be noted that no attempt was made to study whether the ratings effects are linear or curvilinear. The reason for this ommission is that the levels (treatments) of the different ratings (factors) were too few.

A study of Figure 13* makes it possible to reach the following conclusions:

1. An increase in the metropolitan area rating tends to increase the percent occupancy of a parking facility (see Figures 13a and 13b). Therefore, an increase in the level of downtown parking congestion, an increase in the level of radial travel congestion, an increase in the size of metropolitan area, and an increase in the travel speed of transit combine to produce greater utilization of change of mode lots. The rate of occupancy increase averages 2.5 percent per unit of metropolitan area rating.
2. The usage of a change of mode lot seems to increase with an increase in the transit service rating (see Figures 13c and 13d). Thus, improving the transit service (i.e.: reducing fare and headways, and increasing speed and downtown distribution network) would result in an increase in the occupancy of the fringe parking lots. The rate of occupancy increases on an average of less than one percent per unit of transit service rating. Although the total increases in percent occupancy over the range of metropolitan area rating and transit service rating are equal, it would be easier

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*The percent usage, rather than its square root transformation, is used in order to make the graphs easier to read.

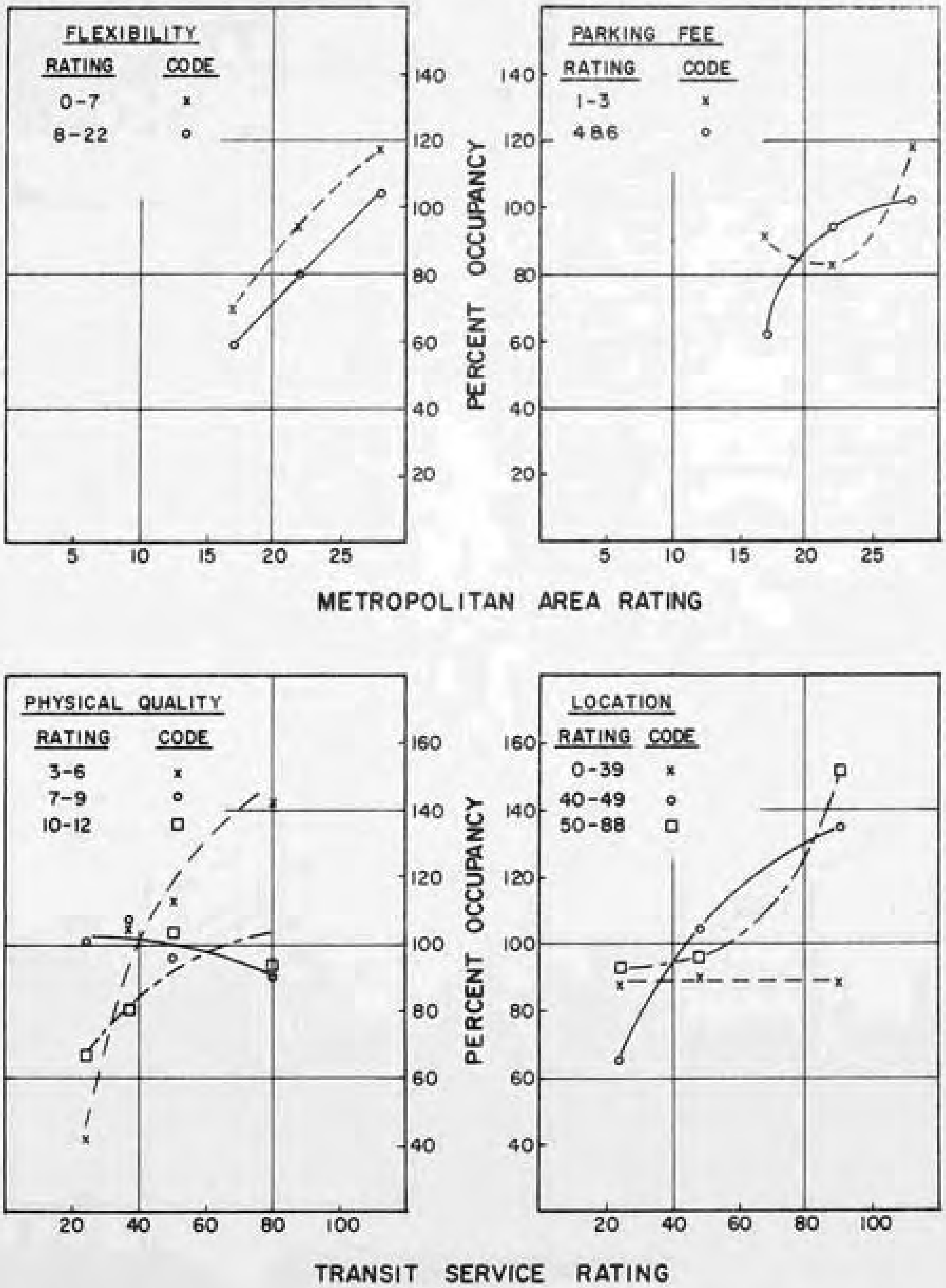

FIGURE 13 TRENDS OF THE RATINGS EFFECTS UPON CHANGE OF MODE PARKING LOT PERCENT OCCUPANCY

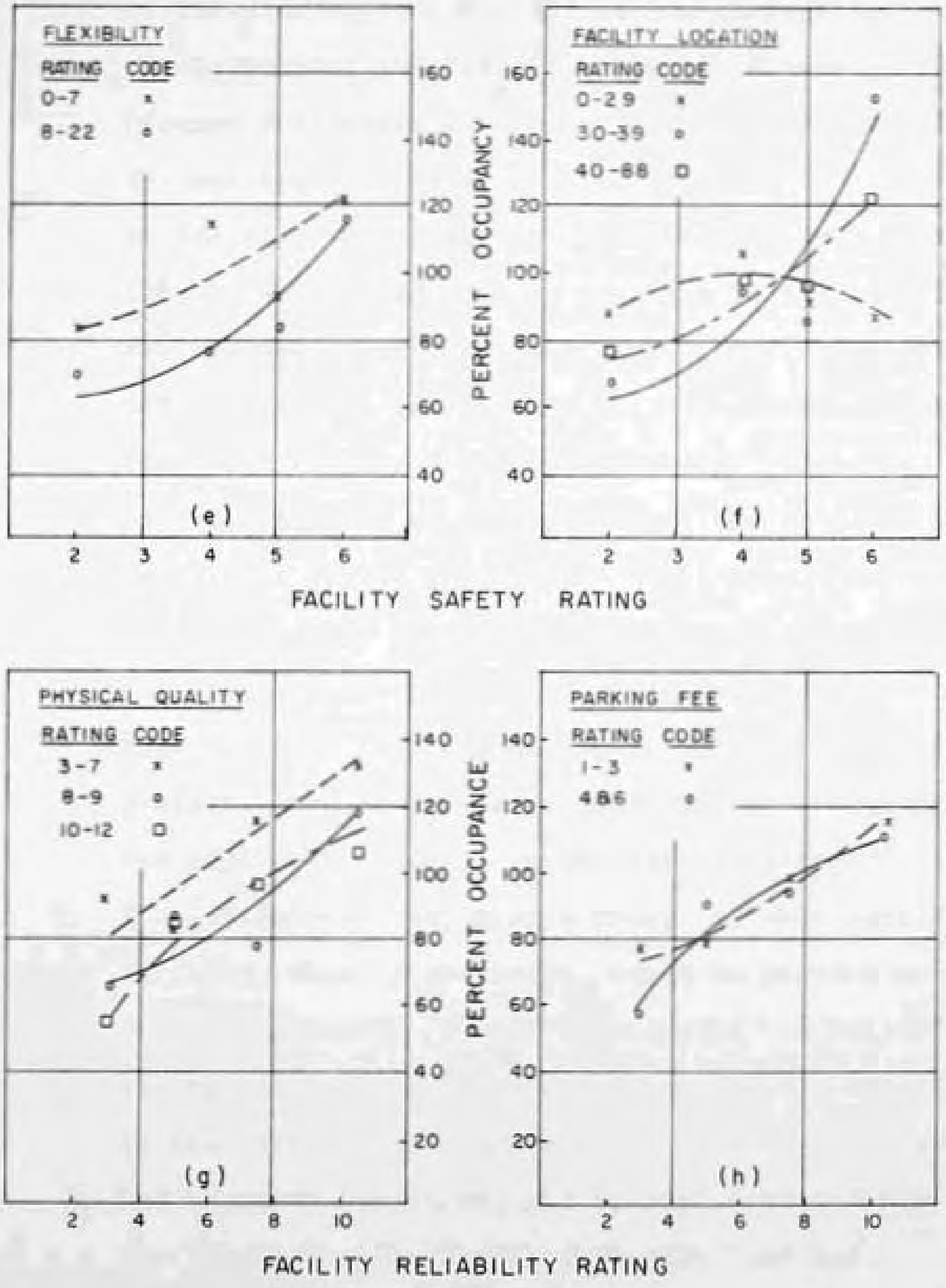

FIGURE 13 (CONTINUED)

to increase the occupancy of a lot through the improvement of the transit rather than through the planned deterioration of the traffic condition in the metropolitan area.

3. An increase in the percent occupancy of park 'n ride lots is associated with an increase in its safety rating (see Figures 13e and 13d). Facilities with adequate egress and ingress, well enclosed and well lighted will have a higher occupancy. Lighting, if present, implies by necessity that the lots are opertional during part of the night time. Safety and reliability (night time operation is a partial measure) are therefore confounded and it is to be expected that they are highly correlated. In the average, percent occupancy increases by ten percent for each unit increase in the safety rating.
4. The reliability rating of a change of mode parking facility, when it increases, tends to produce a higher occupancy. A unit increase in the reliability rating adds on the average a seven percent increase in the occupancy. Therefore, to increase the days and hours of operation, and to employ attendants at the lots makes for a more fully utilized lot. Because of the interdependence of the reliability rating and the safety rating, the change of mode operator is advised to increase both ratings

simultaneously in order to achieve the average increases in the occupancy of his lot.

5. Increases in the physical quality rating, the flexibility rating, and the parking fee rating all tend to decrease the occupancy of a change of mode lot (see Figures 13c and 13g, 13a and 13e, 13b and 13h respectively). This is the opposite of what is expected. A closer look at the data will indicate that facilities with high physical quality and flexibility ratings happen to involve relatively low metropolitan area, safety and reliability ratings (i.e.: relatively small urban areas, poorly enclosed facilities within shopping center lots, and restricted and specialized transit service). The higher significance of the metropolitan area, safety and reliability ratings is an indication that increases in the quality, flexibility and parking fee ratings could be offset by the associated chance decreases in the more significant ratings. This countereffect between the two groups of ratings would lend credence to the proposition that increases in parking lot occupancy could be higher than those reported before.
6. The decrease in parking lot occupancy that is accompanied by an increase in the parking fee rating is due to either underpricing or to the

fact that free parking does not offset the bad effect of poor conditions at the lot. This implies that parking fees, when high could act as a deterrant and when low do not seem to act as an enticement (see Figure 13b). If the occupancy of a facility is low while that of a properly priced competitive lot is high, then raising the parking fee of the second will tend to equalize the occupancy of both. If two facilities differ in only their parking fee the one that is overpriced would be less filled.

7. Although the location rating was found to be non-significant, its interactions with the transit rating were significant. A study of Figure 13d indicates that a major increase in the transit service rating will not affect the bad effect of a poorly located facility. The same could be said for the effect of all other ratings, given a facility with a low location rating. Figure 13d also indicates that the effect of an increase in the transit service rating is compounded when it is associated with an increase in the location rating. Better visibility of a lot from its highway access, smaller access distances, a residential surrounding land use, higher surrounding population densities, and longer transit trips all combine to produce better located facilities.

Recommendations

For the purpose of a more fully utilized change of mode parking facility the following recommendations are proposed:

1. Choose a good location according to Table B2. If a facility already exists, improvements in its visibility and its access are the only things that could be undertaken.
2. Improve the transit service by shortening headways during rush periods. It is better to have a high parking fee and a low transit fare than the opposite, or even a balance between the two. Better transit speed is always advisable.
3. Provide the park 'n ride service for as many hours and days as possible. Rush hour service is necessary but not sufficient to produce a highly used facility.
4. Provide fencing for the lot with well defined entrances and exits if the lot is already in existance. If the lot is new, geometric features must emphasize its boundaries. Better lighting will also produce larger occupancy.
5. Avoid underpricing of the parking at the facility. Low parking fees, or none at all, do not attract users. Better characteristics will offset a moderately high parking fees, while bad

characteristics would not be offset by low parking fees.

6. Higher parking fees in the downtown, if they could be implemented, should be enacted especially if evidence shows that the commuter is receiving the subsidy provided by the short term parkers.

CHAPTER 5: PARK 'N RIDE DEMAND

This Chapter reports on the development of a multiple linear regression equation to predict the change of mode demand. This equation is to apply in all metropolitan areas of the continental United States, and for the forseeable future as long as no major changes occur in present travel and traffic trends, based on the sample taken.

Procedure of Analysis

In the absence of an established theory regarding change of mode demand, one can only assume a model form. One of the possibilities is to assume an additive model. Therefore, one should view the linear equation as only an estimate or an approximation until such time as further evidence is available.

Data and Variables

There are several ways to measure the change of mode demand. Percent occupancy of a lot, which would tie the demand to the size of the facility seems inappropriate. Another measure for change of mode demand is the number of transit passengers whose terminal access mode is by passenger car. However, the interest is in the demand for parking rather than that for transit. In this case, the number of change of mode passengers includes both park 'n ride and kiss 'n ride passengers. It was decided to use the park 'n ride vehicles that use a facility during a twenty four hour period, or a transformation therefrom, as the dependent variable in the regression model. It was also decided not to predict the demand for kiss 'n ride directly because of the lack of sufficient data.

The analysis of variance gave a number of significant main effect and interaction terms that affect the percent occupancy of a parking lot. Since percent occupancy and the number of park 'n ride vehicles are highly correlated variables, it was deemed unnecessary to repeat the analysis of variance for each of the dependent variables. Therefore, the terms that were found to be significant in the analysis of variance were used as the independent variables in the regression analysis. The square of the significant main effect terms were added and used. Three more independent variables were also added: (a) the size of the facility, (b) the type of transit (Bus=0, Rail=1) and (c) the years from start rating (see Table B8), along with their squares.

Change of mode is associated with home to work and work to home trips. Turnover rates at change of mode parking facilities are therefore close to one. Accounting for night time operation and the fact that an occupancy of 85 percent is indicative of a full parking lot in usual cases, it was decided to disregard all observations with a lot occupancy larger than 95 percent. We are interested in estimating only the park 'n ride demand, and not the park 'n ride demand plus some other types of parking demand. The result of this decision was to reduce the available number of observations from 190 to 96, and the number of associated facilities from 93 to 55. The data cover ten metropolitan areas, and involve only those cases where the supply of parking spaces exceeds the demand.

Model and Method

The multiple linear regression model that was used to predict the park 'n ride demand is given by equation 3:

$$(3)\quad Y_i = \beta_o + (\beta_1 x_{1i} + \beta_2 x_{2i} + \ldots\ldots) + (\beta_{11} x_{1i}^2 + \beta_{22} x_{2i}^2 + \ldots\ldots) + (\beta_{12} x_{1i} x_{2i} + \ldots\ldots) + \epsilon_i$$

where:

Y_i = actual park 'n ride demand for ith observation,

$x_{1i}, x_{2i}, \ldots$ = value of first, second, ..., independent variables for ith observation,

β's = true multiple linear regression coefficients,

ϵ_i = error between actual and estimated park 'n ride demand for ith observation.

The method of least squares is used to produce unbiased estimates for the beta coefficients, and the above equation becomes:

$$(4) \quad \hat{Y}_i = b_o + (b_1 x_{1i} + b_2 x_{2i} + \ldots\ldots) + (b_{11} x_{1i}^2 + b_{22} x_{2i}^2 + \ldots\ldots) + (b_{12} x_{1i} x_{2i} + \ldots\ldots)$$

where:

$\hat{Y}_i$ = estimated park 'n ride demand for ith observation,

b's = estimated multiple linear regression coefficients.

In order that the b's be unbiased estimates of the β's the following conditions must be satisfied:

1. ε_i's are normally distributed with mean equal to zero
2. ε_i's are independent of the x's, and therefore have a constant variance (σ_E^2).

The regression analysis was performed at the Purdue University Computer Science Center. BMD2R is the statistical computerized library program used to derive equation 4. This program uses a stepwise technique, where the best* independent variable is entered first and the worst is entered last.

All the independent variables were developed (see Chapter Three) in such a manner that an increase in their value should logically produce an increase in the demand for

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*best is that which provides the highest simple correlation coefficient.

park 'n ride. For this reason, if an independent variable entered the regression equation with a negative coefficient it was deleted from the stepwise process unless it had previously entered or subsequently entered the equation under a different form and with a positive coefficient. A regression equation that is thus developed will always produce increases in the demand when any of the independent variables increase, and a decrease in the demand when any of the independent variables decrease.

A regression equation was developed to predict the number of park 'n ride vehicles. The equation was later tested to see if it satisfied the statistical constraints placed on the error term in the regression model. The Bartlett test for homogeneity of variance was used to test for both normality and independence. The Bartlett test produced a high χ^2 indicative of the fact that the equation violated its inherent constraints. For this reason the dependent variable was mathematically transformed into its square root, and the whole process was repeated.

Prediction Equation

The discussion that follows reports on the chosen park 'n ride demand prediction equation. The statistical qualities of the equation are given, and comments are made on the makeup of the equation. Also, both sensitivity and applicability analyses are included.

Results

Equation 5 is the chosen prediction equation:

$$(5) \quad \sqrt{D} = 0.70479 + 0.00940\,Z + 1.96438\,B + 1.21122\,R + 0.00088\,T^2 + 0.00867\,M^2 + 0.04868\,F \cdot P - 0.01929\,T \cdot R$$

where

D = number of park 'n ride vehicles that use a facility during a 24 hour period,

Z = total number of stalls within a change of mode parking facility,

B = type of transit being transferred to at the facility (bus on highway right of way = 0, rail and bus on exclusive right of way = 1),

R = reliability rating of the change of mode parking facility (see Table B6),

T = transit service rating at the change of mode parking facility (see Table 4),

M = metropolitan area rating for the change of mode parking facility (see Table B1),

F = flexibility rating of the change of mode facility (see Table B5),

P = parking fee rating of the change of mode facility (see Table B7).

Table 12 summarizes the statistical qualities of the chosen prediction equation. Equation 5 explains 78 percent of the variation in the park 'n ride demand, and has a multiple correlation coefficient $R = 0.88$. All the independent variables are significant at the 95 percent level, and all but one are significant at the 99 percent level. The equation on the whole, with an F-ratio of 44.2, is significant at a much higher rate than 9995 in ten thousand. The standard error of the estimate is equal to 2.93, which implies that the 95 percent confidence interval of an estimate is from 56 to 369 parked vehicles per day.

The chosen equation was tested for homogeneity of variance using the Bartlett test. A χ^2 equal to 5.81 was obtained with four degrees of freedom. Since the critical χ^2 at the ten percent level (7.78) is larger than the computed one, the hypothesis of homogeneity of variance and normality of the error term is accepted.

Two of the design ratings did not enter into the prediction equation. The safety rating had a high correlation with the reliability rating, and the physical quality rating was substantially correlated to the parking fee rating. Both, the reliability and the parking fee ratings affected the park 'n ride demand more significantly and once in the equation they barred the entry of the latter two.

TABLE 12. STATISTICAL QUALITIES OF PREDICTION EQUATION

Step Number	Variable Name	Regression Coefficient	Standard Error	F-Ratio	R^2	Increase in R^2
		-0.70479				
1	Z	0.00940	0.00095	98.4812	0.6244	0.6244
2	B	1.96438	0.90511	4.7103	0.6957	0.0713
3	F·P	0.04868	0.01255	15.0351	0.7105	0.0149
4	R	1.21122	0.26075	21.5779	0.7289	0.0183
5	M^2	0.00867	0.00291	8.8602	0.7413	0.0124
6	T·R	-0.01929	0.00509	14.3574	0.7564	0.0151
7	T^2	0.00088	0.00030	8.8465	0.7786	0.0222

Sensitivity

The object of this discussion is to show what happens to the park 'n ride demand when the independent variables in the prediction equation take on different values. Figures 14a through 14f are given for this purpose. The solid lines represent the change in park 'n ride demand when one independent variable is changed, while all remaining six variables are kept constant at their observed mean. The dashed lines are for the cases when all remaining six independent variables are kept constant at the two thirds percentile. The figures are self explanatory, however the following should be noted.

1. For a 200 stall lot, with all remaining independent variables constant at their minimum values, the park 'n ride demand is estimated at six vehicles per day, and therefore a 3 percent occupancy;
2. For a 2000 stall lot equation 5 can predict a maximum demand of over 3,000 park 'n ride vehicles per day, and 150 percent occupancy;
3. Using the data mean values of the independent variables, a demand of 185 park 'n ride vehicles per day is estimated;
4. On the average the type of transit is the term that contributes the least proportion (5.2 percent) toward our estimate of the park 'n ride demand, while the reliability rating term contributes the highest (27.5 percent).

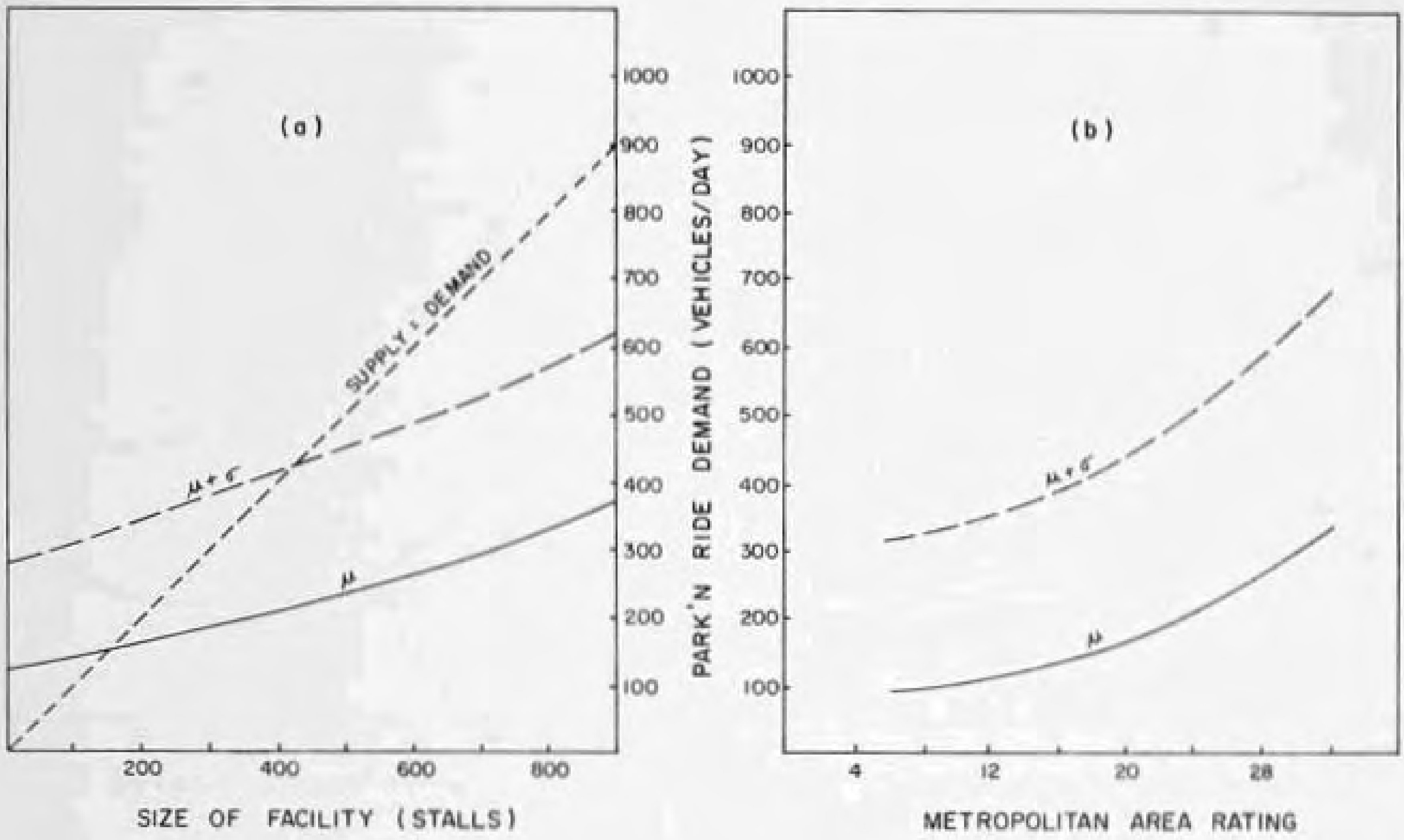

FIGURE 14 SENSITIVITY OF PARK'N RIDE DEMAND EQUATION

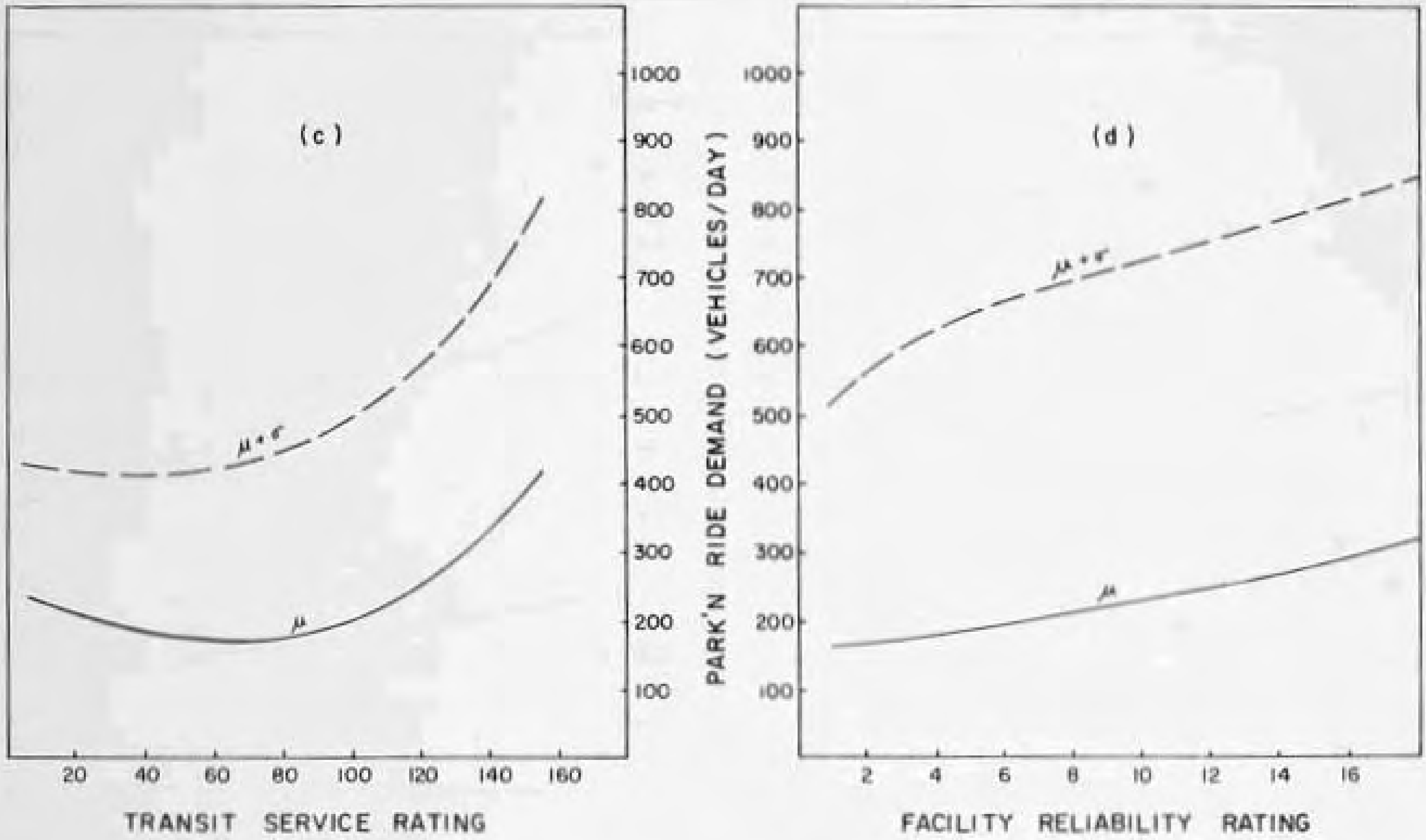

FIGURE 14 (CONTINUED)

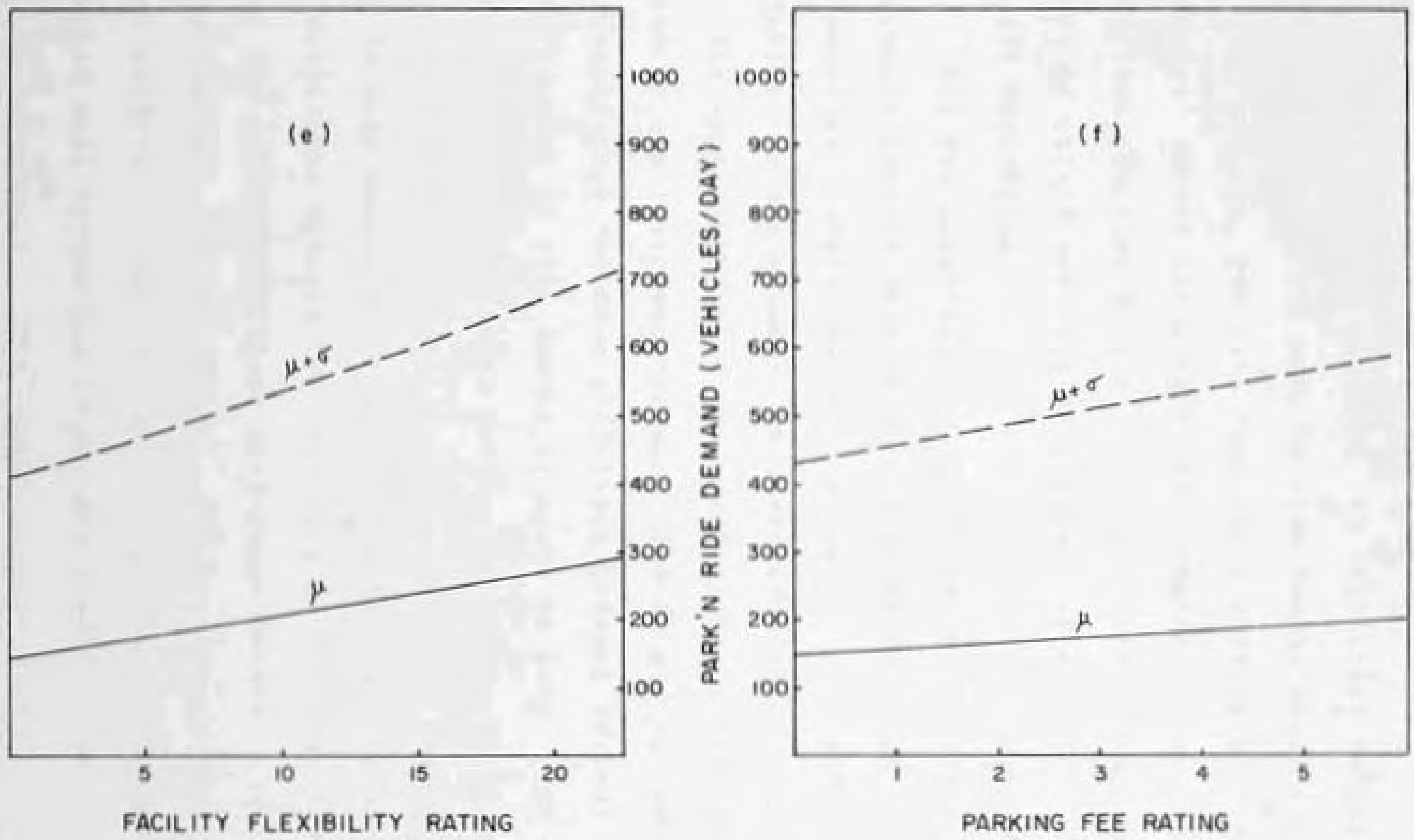

FIGURE 14 (COUNTINUED)

Applicability

At this point, a check on the regression equation's ability to predict the park 'n ride demand seems appropriate. For this purpose, the data from the Institute of Traffic Engineers' survey was used to test whether or not the prediction equation does a good job of predicting the number of parked vehicles at a change of mode lot. Out of the 179 facilities that the ITE surveyed only nine were used. All the remaining 170 facilities were either previously used in developing the equation, didn't contain the necessary information to compute the independent variables, or had a demand that exceeded the supply.

The applicability of the prediction equation was tested by two different methods. The first test was on the hypothesis that the mean difference between estimated and measured park 'n ride demand is equal to zero. The Student-t test was used to either accept or reject the hypothesis. Table 13 gives the observed and estimated park 'n ride demand for the nine checked facilities, and the difference between. A Student-t of 0.91 was computed using the paired comparison difference between observed and estimated park 'n ride demand. The hypothesis that there is no difference between observed and estimated demand is accepted well beyond the 20 percent level*. The critical

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*See Kurtz (28), p. 312, for a table of the critical Student-t.

TABLE 13. OBSERVED AND ESTIMATED PARK 'N RIDE DEMAND
(P.C. - PASSENGER CARS)

Observed Demand		Estimated Demand		Difference
$(P.C./day)^{1/2}$	P.C./day	$(P.C./day)^{1/2}$	P.C./day	
5.00	25	6.64	44	-1.64
22.36	500	17.62	311	4.74
20.00	400	15.37	235	4.63
10.72	115	11.88	141	-1.15
8.06	65	5.70	33	2.37
11.00	121	8.42	71	2.58
27.39	745	18.33	336	9.06
7.42	55	13.51	183	-6.09
10.30	106	12.38	153	-2.08

Student-t for an α of 0.2 and eight degrees of freedom is equal to 1.40 which is much larger than the computed one. Since the hypothesis is accepted even at an α equal to 0.2, this indicates that the probability of accepting when one should reject is very low.

Next, the individual estimates were tested. For this purpose a least square regression equation is developed for the observed demand, with the estimated demand being the sole independent variable. If the individual estimates are equal to the corresponding observed demand, then the equation would have a zero intercept ($b_0 = 0$), and a slope of forty-five degrees ($b_1 = 1$). An F-ratio* was used to test the hypothesis that the regression equation for the estimated versus observed demand possesses a b_0 and a b_1 coefficients that are equal to zero and one respectively. Simultaneously, an F-ratio of 1.22 was computed, and the hypothesis is accepted up to the 34 percent level.

In conclusion, an equation that satisfies the statistical constraints that are inherent in a linear regression model has been developed. This equation is also able to reliably predict the park 'n ride demand at different facilities and in different metropolitan areas.

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*See Ostle (27), p. 175 for a description of the test.

CHAPTER 6: THE ECONOMICS OF CHANGE OF MODE

The purpose for studying the economics of change of mode is twofold; first is to decide on its feasibility; and secondly is to base the selection of parking lot design criteria on a quantitative basis. As will be shown later, a commuter saves money when he uses both the transit and his car rather than relying completely on his car to complete the trip to downtown. However, in order to incur such savings, the commuter must be provided with the space to park and change mode, and this means that an expenditure must be made. A change of mode parking facility is economically feasible if the return on the investment, due to the savings, is at an acceptable rate.

Parking Facility Costs

Two types of costs are involved; first is the capital investment, and secondly is the running cost of operating the change of mode parking facility. The running costs are computed as a function of the ratings used to estimate the park 'n ride demand. The desirability of such an approach will become evident when selecting parking lot design criteria.

Capital Investment

The only capital outlays considered are those relating directly to parking. For example, the cost of the transit station terminal at the change of mode facility is not considered. The investment costs are: (a) land cost, (b) construction costs.

The market value of the land for change of mode parking facility is used as the land cost, whether the land is already owned by the transit agency or is to be leased on a yearly basis, the situation is not changed. In the first case, they could sell the plot to a private investor, and invest the capital. In the second case, the lessor is extracting a return on the market value of his land as rent. Appendix D contains Figures 4D, 5D and 6D which can be used to compute land values at different locations within different metropolitan areas. In Washington, it was found that land values at acceptable locations range from two to four dollars per square foot (6). This compares well with values from the above three mentioned figures.

Construction costs are made up of the following:

a. Costs to clear and grade the lot, and to provide adequate street access.

b. Pavement and landscaping costs.

c. Lighting costs.

d. Costs to provide for adequate enclosures, entrances and exits.

The costs of clearing, grading and providing access to change of mode lots vary from one to seven dollars per square foot of parking lot, with an average of 2.4 (12). The higher values are associated with interchange change of mode situations, while lower values correspond to the existing street layout.

Pavement and landscaping costs vary depending on how well the facility is physically constructed. For high quality construction, pavement and landscaping costs run about half a dollar per square foot (29). This unit cost includes provisions for marking, pedestrian sidewalks, bus berths and kiss 'n ride stalls.

Average unit costs for good lighting, adequate enclosures around the lot and well defined entrances and exits could run to approximately a quarter of a dollar per square foot (29). Good standards of lighting require underground wiring, 30 foot luminaire mounting height, and about one pole for every fifteen spaces. Adequate enclosing of the lot could be achieved by fencing it.

An average total unit construction cost for high quality change of mode parking lots, where streets exist as opposed to interchange areas, runs between 2.50 to 3.00 dollars per square foot. All the unit costs given above are in 1970 dollars.

Running Costs

Operating and maintenance costs are the two components of the running cost which includes the salaries paid to attendants, insurance for liability, taxes, utilities, maintenance, and overhead. On the other hand, the reliability rating depends on the number of attendants employed, the number of hours and days of operation, and the maintenance level at the parking facility. Therefore the running cost is a function of the reliability rating. Table 14 gives the running cost for different values of the reliability rating, and equation 6 formulizes the dependence of the running cost on the reliability rating.

$$(6)\quad \begin{array}{l}\text{Running Cost}\\ (\$/\text{stall-year})\end{array} = 130 + 5.80\ R$$

R is the reliability rating of the change of mode facility.

A parking fee, if charged at the parking lot, reduces the running costs by providing a daily income to the change of mode operator. Equation 7 gives the parking revenue as a function of the parking fee rating P,

$$(7)\quad \begin{array}{l}\text{Parking revenue}\\ (\$/\text{stall-year})\end{array} = \frac{D}{Z}\ (570 - 215\ P + 20\ P^2)$$

where D is the number of park 'n ride vehicles per day, and Z is the number of stalls at the change of mode facility. The net running cost is then given by equation 8.

$$(8)\quad \begin{array}{l}\text{Net running cost}\\ (\$/\text{stall-year})\end{array} = (130 + 5.80\ R) - \frac{D}{Z}\ (570 - 215\ P + 20\ P^2)$$

TABLE 14. RUNNING COSTS AND ASSOCIATED RELIABILITY RATING

Reliability Rating	Running Costs* ($/stall-year)			
	Insurance & Taxes	Utilities & Maintenance	Salaries	Total
0	40	0	90	130
3.8	40	6	106	152
9.5	40	15	130	185
19.0	40	30	170	240

*Parking, by ENO was used as the source for developing the unit running costs (30).

Equations 6, 7 and 8 are all expressed in terms of 1970 dollars.

Community Savings

Community savings are defined as the difference in total costs between driving all the way to the downtown and driving to a change of mode parking lot and taking the transit for the remaining part of the trip. Cost elements are taken from the existing literature, and average values are used exclusively.

Travel Costs

The units for travel costs by passenger car are in dollars per vehicle-mile. The units for travel costs by transit are in dollars per passenger-mile. The travel cost elements by passenger car are the vehicle operation, accident, and pollution costs. The transit fare is the only cost element for travel by transit. There are other cost elements that enter in the analysis of commuter savings, and these will be discussed later.

Driving conditions change with the type of highway being used. The street network is subdivided into four types: expressways, arterials, local streets and downtown streets. Unit travel costs are thus developed by type of highway in order to account for changes in driving conditions. Table 15 gives the unit costs for travel by passenger car. Vehicle operating costs include licenses, depreciation,

TABLE 15. UNIT TRAVEL COSTS FOR PASSENGER CARS, BY HIGHWAY TYPE

(1970 DOLLARS)

Highway Type	Vehicle Operation* ($/veh-mile)	Pollution+ ($/veh-mile)	Accident*+ ($/veh-mile)
CBD Streets	0.143	0.023	0.007
Local Streets	0.128	0.015	0.007
Arterials	0.123	0.012	0.005
Expressways	0.113	0.006	0.002

*Source: References number 31, 32, 33.

+Source: References number 34, 35.

*+Source: References number 31, 36, 37.

vestcharge, insurance, parking, tolls, taxes, oil, gasoline, maintenance and tires (see Table D1 and D2). Pollution costs are computed on the basis of cost estimates for control devices, and not on the damage that is caused by auto emissions (see Table D3 and Figure D1). Unit accident costs include all types of accidents, and are computed for passenger cars in urban areas (see Table D4).

Transit fare costs are computed based on existing fares in Cleveland (rail) and Milwaukee (bus), and on the proposed fares for San Francisco (rail), (19,18,5). Equation 9 is developed to estimate transit fares in dollars per passenger mile (see Figure D2).

$$(9)\quad \text{Transit fare} = 0.20\ (\text{Transit Trip Length})^{-0.646}\ (\$/\text{passenger-mile})$$

Equation 9 is expressed in terms of 1970 dollars, and the transit trip length is in miles.

Related Costs

The related costs are those that account for time, land productivity and parking fees. Since change of mode trips are work trips, one should account for the cost of time. When a parcel of land is used as a parking lot there ensues a land productivity loss, since the land could have been used for more productive purposes.

The value of time for work trips is assumed to be equal to 1.25 dollars per person-hour (38). Assuming average travel speeds and average car occupancy, the travel time cost becomes equal to 0.187, 0.100, 0.081 and 0.046

($/vehicle-mile) for CBD streets, local streets, arterials, and expressways respectively (33,39,40), (see Table D5). Similarly, the cost of time for travel by transit becomes equal to 0.059, 0.042 ($/passenger-mile) for express bus and rapid transit respectively (19,18,33,40), (see Table D6). Time is also spent at both ends of a trip. This terminal time is assumed to be equal to 7 (minutes/person) for a one way trip by passenger car (41), 6.5 and 10.0 (minutes/person) for a one way kiss 'n ride trip by rail and bus respectively, and 7.5 and 11.0 (minutes/person) for a one way park 'n ride trip by rail and bus respectively (see Table D7).

The loss of land productivity is assumed to be equal to ten percent of the land value. Figures 4D, 5D and 6D can be used to determine the land value for any change of mode parking lot. The land value of downtown parking has been assumed to be equal to 2,000 dollars per stall (42).

Parking fees in the downtown are computed on the basis of existing rates (42). Equation 10 is developed to estimate parking fees in the downtown of metropolitan areas in dollars per vehicle (see Figure D3), and only applies for work trips.

$$\text{(10)} \quad \text{Downtown parking fee } (\$/\text{vehicle}) = 0.84 \log \left(\frac{\text{Metro. Area Pop.}}{34} \right)$$

The Metropolitan Area Population is in thousands of persons. The parking fee at a change of mode lot is given by equation 11 as a function of the parking fee rating P:

$$\text{(11)} \quad \text{Parking fee} = 1.90 - 0.717P + 0.0667P^2$$
(\$/vehicle)

All of the related costs are expressed in terms of 1970 dollars. It is important to note at this stage that highway and transit construction and operation costs are not to be included in the analysis of commuter savings from change of mode. The purpose of the analysis is to study the feasibility of change of mode, and not that of the transit versus the highway.

Simulation of Community Savings

A computer program was written in Fortran IV to simulate the community savings. A copy of the program is attached in Appendix E. The savings are computed for a combination of six metropolitan areas, seven parking lot distances to the CBD, two types of transit, four proportions of kiss 'n ride stalls to total stalls, and three parking lot distances to the street access. A total of 1008 different conditions are therefore analyzed. The community savings, as simulated by the program, are later used to develop a multiple linear regression relating the community savings to the size of metropolitan area, type of transit, distance of lot to CBD, distance of lot to its street access, and to the proportion of kiss 'n ride stalls to total stalls.

The simulation program computes the cost of traveling by passenger car to the downtown, and the cost of traveling by passenger car to a change of mode lot and taking the transit to downtown. The two travel alternatives are shown in Figure 15. The elements of cost for a trip by passenger car to the CBD are the following:

a. vehicle operation
b. vehicle emissions
c. vehicle accidents
d. travel time
e. terminal time
f. CBD parking fee
g. loss of land productivity in downtown.

The elements of cost for a trip by passenger car and transit (change of mode trip) to the CBD are the following:

a. vehicle operation for auto portion of the trip
b. vehicle emissions for auto portion of the trip
c. vehicle accidents for auto portion of the trip
d. travel time for auto portion of the trip
e. travel time for transit portion of the trip
f. terminal time
g. transit fare
h. change of mode parking fee*
i. loss of land productivity at change of mode lot

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*The change of mode parking fee is not included in the simulation program, but is later added (see equation 13).

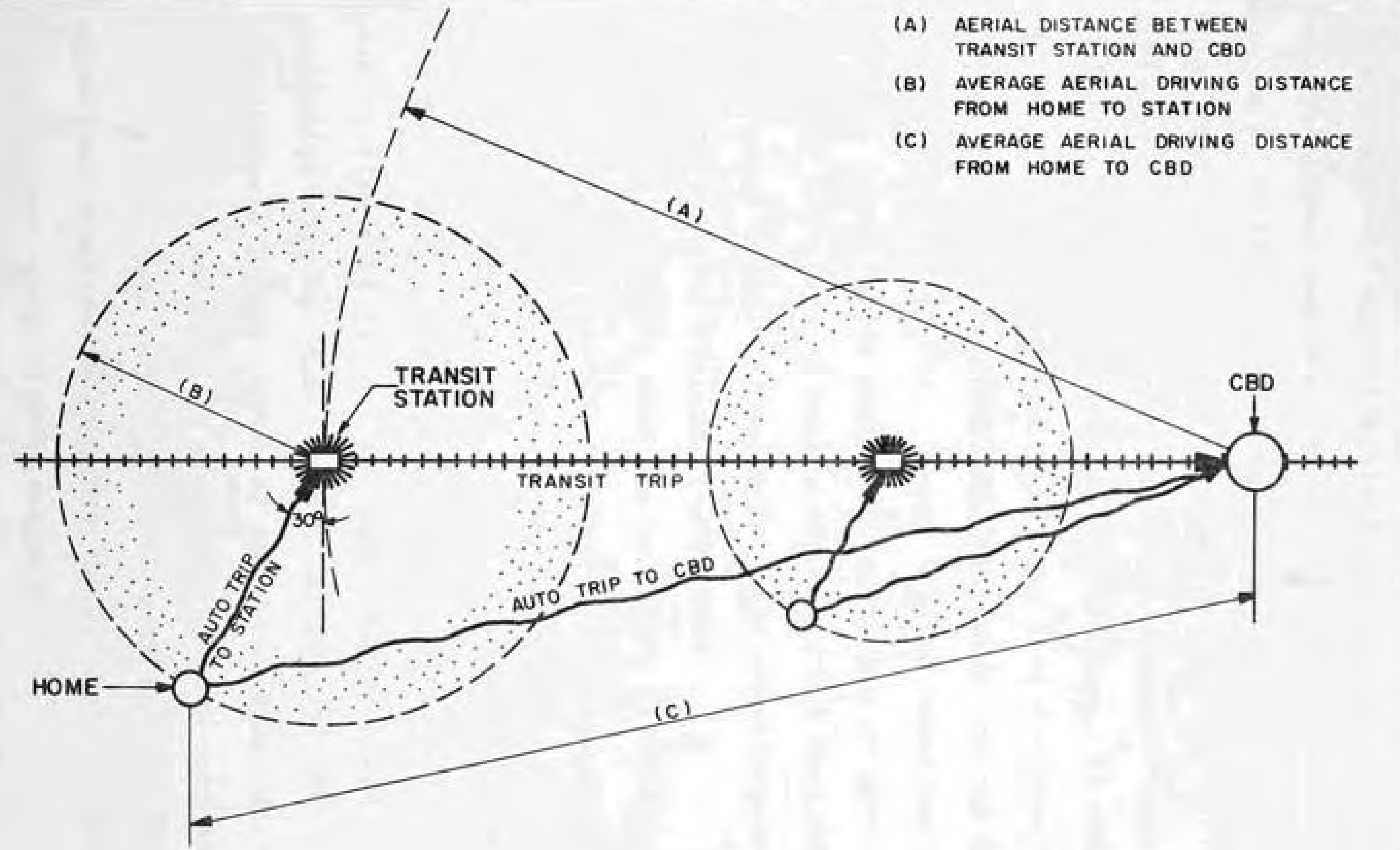

FIGURE 15 SCHEMATIC REPRESENTATION OF CHANGE OF MODE PROCESS

A number of cost elements have been developed on a vehicle-mile or passenger-mile basis. Since actual costs are to be determined for a trip, the need for estimating trip lengths is apparent. Figure 16 gives the average air distance from a commuter's home to a change of mode lot as a function of the air distance of the change of mode lot to the CBD. This figures was developed from the results of surveys conducted in Cleveland, Milwaukee, Boston and Chicago (19,18,4,10,20). Beyond a given point the average distance from home to change of mode lot decreases. This is due to the start of finger type land use development along radial corridors, and not to the unwillingness of commuters to drive additional distances.

Travel distances that are less than 0.4 miles are made on local and CBD streets. Travel distances in excess of 1.9 miles are made on expressways. The balance between 0.4 and 1.9 miles is the distance driven on arterials (43).

The community savings are computed in dollars per park 'n ride vehicle per day. In order to accomplish this, cost units must be transformed. The key for the transformation of unit costs is the number of change of mode passengers (park 'n ride and kiss 'n ride) per park 'n ride vehicle. The collected data (see Chapter 3) were used to develop a regression equation to estimate the change of mode passengers per park 'n ride vehicle.

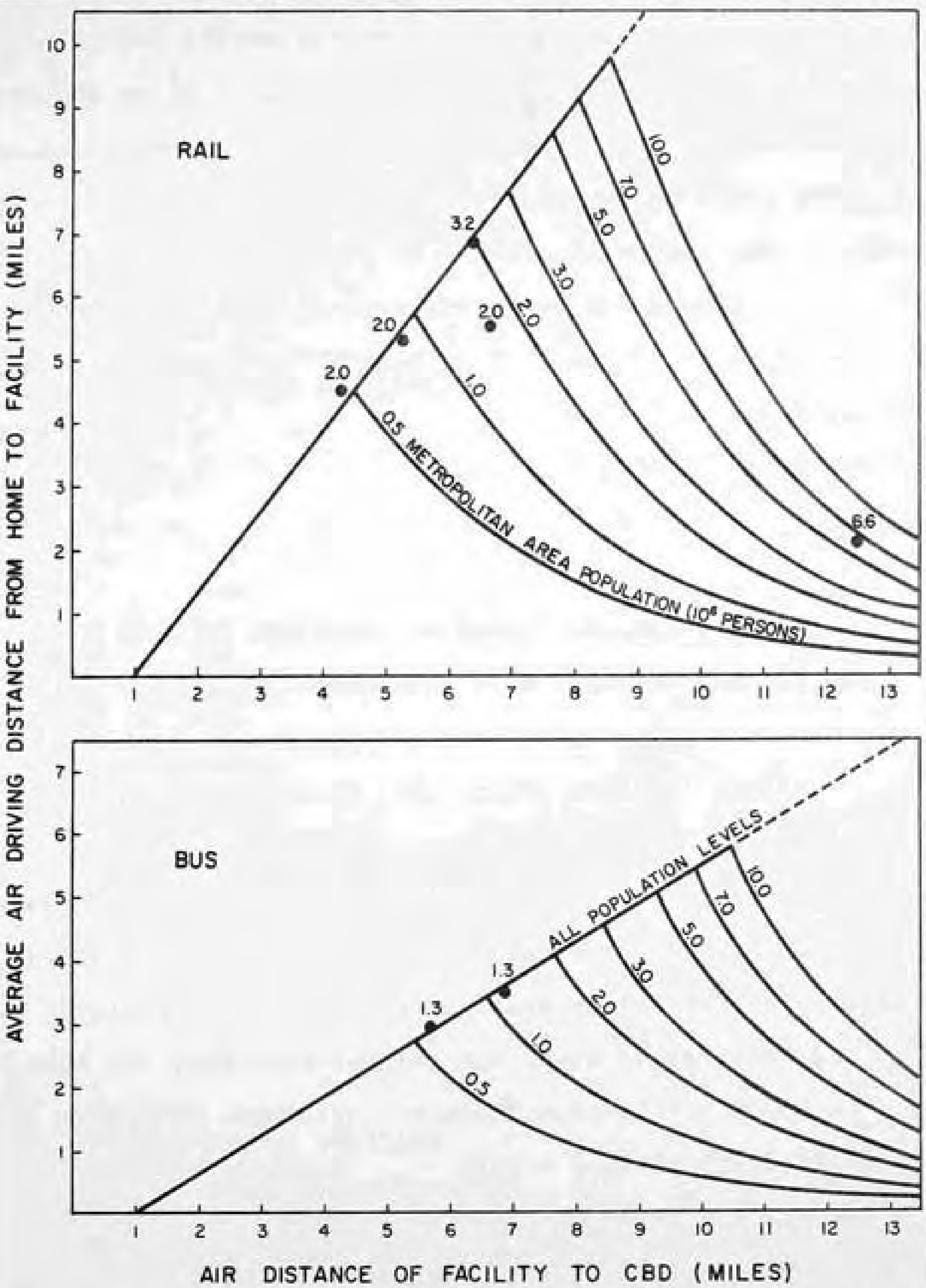

FIGURE 16 AVERAGE DRIVING DISTANCE FROM HOME TO CHANGE OF MODE PARKING LOT(4,10,18,19,20)

The ITE survey indicated that community savings accrue from one in five park 'n ride vehicles (13). The simulation program takes this fact into account. As mentioned earlier, the computer program was used to simulate savings, which becomes one of the inputs to a packaged regression program. The results of this process are given by equation 12.

(12) Community Savings ($/parked vehicle)

$$= 0.40627 + 0.00002\ p + 0.04498\ d - 0.15028\ t - 0.00261\ k + 0.00193\ d^2 - 0.00001\ p \cdot d$$

where

p = size of metropolitan area (thousand persons)

d = distance from change of mode lot to CBD (miles)

t = type of transit (Rail = 1, Bus = 2)

k = percent kiss 'n ride stalls to total stalls.

Equation 12 possesses an R^2 of 0.97, and all of its independent terms are significant at a rate higher than 9,995 in ten thousand. The net community savings, which are obtained by subtracting the parking fee at the change of mode lot from equation 12, are given by equation 13.

(13) Net Community Savings ($/parked vehicle)

$$= 0.02627 + 0.00002\ p + 0.04498\ d - 0.15028\ t - 0.00261\ k + 0.00193\ d^2 - 0.00001\ p \cdot d + 0.143\ P - 0.0133\ P^2$$

where P is the parking fee rating.

Under present conditions, the net community savings vary from zero to two dollars per park 'n ride vehicle per day. Larger savings occur when the change of mode lot is farther from the downtown and its parking fee rating is higher.

CHAPTER 7. APPLICATION

This chapter presents the procedure necessary for developing successful design criteria for change of mode parking lots. A park 'n ride demand prediction equation was developed in Chapter 5. The savings that accrue to a community from change of mode parking and the cost of providing such parking have been determined in Chapter 6. These results are combined to maximize the benefits to a community, from a change of mode parking lot, with respect to the design variables in order to obtain the successful design criteria.

Problem Statement

Successful design criteria are defined as those values of the design variables that maximize the benefits to a community from the provision of a change of mode parking lot. The benefits (the objective function) are maximized under several constraints. The rate of return on the capital outlay for procuring and constructing the lot must be equal to or greater than an acceptable minimum. The running costs as defined by equation 8 must be equal to or greater than zero. This constraint allows the procurement of federal subsidy. The percent occupancy of a lot cannot exceed 95 percent.

Below, the constrained maximization problem is stated in mathematical terms:

(14) Maximize $B = V \cdot D \cdot o - Z\,(C_i \cdot a \cdot crf_{(j,n)} + C_r)$

Such that the following constraints are met:

(15) $V \cdot D \cdot o \geq Z\,(C_i \cdot a \cdot crf_{(j,n)} + C_r)$

(16) $C_r \geq 0$

(17) $(D/Z) \leq 0.95$

where:

B = Benefits of a community from a change of mode parking lot ($/year).

V = Net savings of a community ($/vehicle). V is given by equation 13.

D = Park 'n ride demand at the change of mode lot (vehicles/day). D is given by equation 5.

o = Number of equivalent week days in a year.

Z = Size of the change of mode lot (stalls).

C_i = Capital investment in the change of mode lot ($/square foot). C_i is the sum of the land and construction costs. Land values are determined from figures D4, D5 and D6. Average construction costs are given in Chapter 6.

a = Size of a parking stall (square feet/stall).

$crf_{(j,n)}$ = Capital recovery factor for a life of n years and a rate of return j on investment.

C_r = Running costs of the change of mode lot (\$/stall-year). C_r is given by equation 8.

It should be noted that the objective function (equation 14) is non-linear, and contains a mixture of continuous and discrete terms. A search procedure is employed as the problem revolves around a specifically proposed change of mode lot. This implies that many of the terms in the objective function are actually parameters rather than variables, thus reducing the magnitude of the search for maximum benefits.

A computer program in Fortran IV solves equations 14 through 17, and is attached in Appendix F. Once a specific location is chosen for the change of mode lot, many of the terms in the objective function become constant, and become the input to the computer program. The output of the program is the successful change of mode criteria for that specific change of mode parking lot.

Example

A hypothetical change of mode parking lot is taken as an example to show the method of determining successful design criteria. First, the needed data are given, second, the input to the computer program is developed, and finally the output of the program is analyzed to determine the design criteria.

The Setting

A plot of land is chosen to accommodate a change of mode parking facility at the 86th Street (Nova) station along the proposed Monon line in Indianapolis, Indiana (see Figure 17). Regarding the plot of land, the following data is needed:

a. Lot size: 800 stalls, exclusive of the area reserved for landscaping (15 percent of total).
b. Size of stall: 350 square feet.
c. Lot distance to CBD: 10 miles.
d. Lot distance from its arterial access: 4 blocks.
e. Lot owner: public transit agency.
f. Lot operator: public transit agency, same as that for the Monon line.
g. Length of park 'n ride service: 6 days/week, 10 hours/day.
h. Connecting bus lines: bus berths are to be provided at the lot.

The proposed Monon line has the following qualities:

i. Type of transit: rail rapid transit.
j. Transit terminal building at change of mode lot: adequate.
k. Transit fare to CBD: 0.50 dollars
l. Overall transit speed to CBD: 32 miles/hour.
m. Distribution system of transit line in downtown: one station.

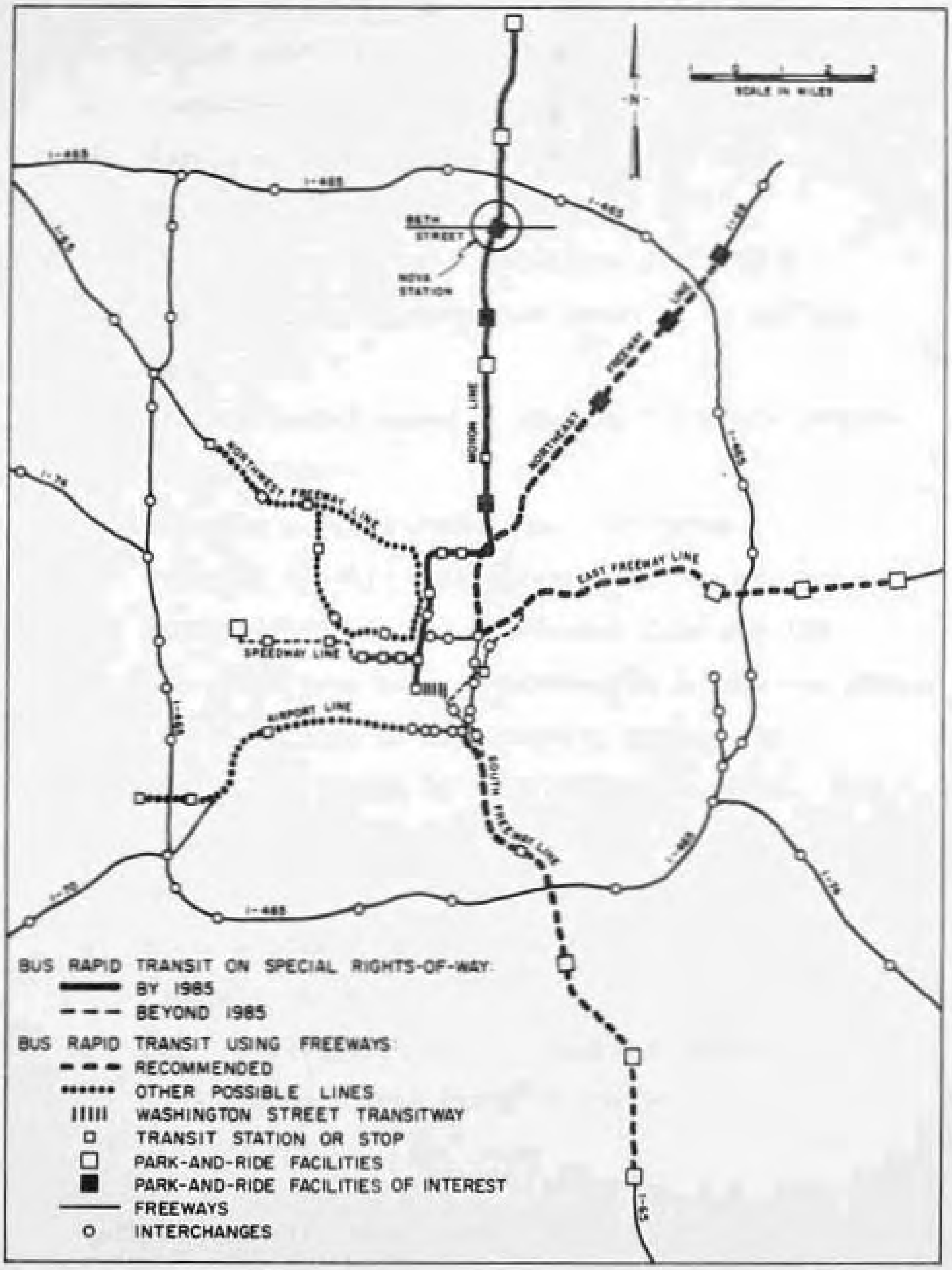

FIGURE 17 THE RECOMMENDED TRANSIT PLAN WITH PROPOSED CHANGE OF MODE LOTS, INDIANAPOLIS

n. Ticket marketing and collection: good methods.

o. Transfers within transit system: allowed and free.

p. Fare zone along transit line: more than one zone along the Monon route.

The city of Indianapolis is described as follows:

q. Population of metropolitan area: 1.05 million persons.

r. Average travel speed of the whole transit system: 21 miles/hour.

s. Downtown parking condition: worrisome.

t. Arterial traffic congestion along transit route: starts at about four miles away from the CBD.

All the data items have been furnished for a date ten years (half the economic life of the project) beyond the inauguration of the change of mode parking service. The following economic assumptions need to be made:

u. Economic life of change of mode lot: 20 years.

v. Minimum acceptable rate of return on invested capital: 0.06.

w. Unit construction cost of parking facility: 1.85 $/square foot (1970 dollars)

Input

Each of the seventeen input items is developed below, and in the order in which the inputs are read into the program.

a. Maximum facility size (IZMAX)*: is the lot size as given by data item a (800 stalls).

b. Stall size (STALL): is the area occupied by a stall and the aisles needed for circulation, as given by data item b (350 square feet/stall).

The above two input items are punched on a single computer card in the format: I5, F5.0 (see Figure 18).

c. Minimum flexibility rating (MINFLX): using data items e, f and h in conjunction with Table B5 the minimum flexibility rating is computed to be equal to 14, (see Chapter 3 for a sample computation).

d. Maximum flexibility rating (MAXFLX): is equal to the minimum flexibility rating plus eight, thus 22.

The above two input items are punched on a single computer card in the format: 2I5.

e. Economic life length of change of mode facility (LIFE): is given by data item u, (20 years).

f. Minimum acceptable rate of return on invested capital (ROR): is given by data item v, (0.06).

g. Unit construction cost of parking facility (CCONST): is given by data item x, and includes the costs of providing access, clearing and grading the lot in addition to the actual construction, (1.85 $/square foot, 1970 dollars)

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*Capitalized alphanumeric mnemonics refer to the names given to the input items of the program.

PUNCHED DATA	MNEMONICS	FORMAT
800 350.	IZMAX, STALL	I5,F5.0
14 22	MINFLX, MAXFLX	2I5
20. 0.06 1.85	LIFE, ROR, CCONST	3F5.0
1.4 16.4 280.	RELMIN, RELMAX, DAYS	3F5.0
10. 4.	FACDIS, ARTDIS	2F5.0
104. 2. 1.	TRNST, RORB, TYPE	3F5.0
1050. 22.	POPULIN, MAREA	F6.0, F4.0

FIGURE 18 SAMPLE DATA FOR DESIGN CRITERIA COMPUTERIZED PACKAGE

The above three input items are punched on a single computer card in the format: 3F5.0.

h. Minimum reliability rating (RELMIN): using data item g in conjunction with Table B6 the minimum reliability rating is computed to be equal to 1.4.

i. Maximum reliability rating (RELMAX): is equal to the minimum reliability rating plus fifteen, thus 16.4.

j. Equivalent weekdays the facility is open during the year (DAYS): if the parking facility is open 5 days per week enter 260, if it is open 6 days enter 280, and if it is open 7 days enter 300. In the present case, and using data item g, DAYS = 280.

The above three input items are punched on a single computer card in the format: 3F5.0

k. Change of mode parking facility distance to CBD (FACDIS): is given by data item c, and is the aerial distance, (10.0 miles).

l. Distance of lot from its arterial access (ARTDIS): is given by data item d, (4 blocks).

The above two input items are punched on a single computer card in the format: 2F5.0.

m. Transit service rating (TRNST): using data items j through p in conjunction with Table 4 the transit service rating is computed to be equal to 104.

n. Type of transit (RORB): if the line is rapid rail or bus on separate right of way (reversible lane) enter two, and if the line is express bus on highway right of way enter one. In the present case, and using data item i, RORB = 2.

o. Type of transit (TYPE): if the line is rapid rail or bus on separate right of way enter one, and if the line is express bus on highway right of way enter two. In the present case, and using data item i, TYPE = 1.

The above three input items are punched on a single computer card, in the format: 3F5.0.

p. Metropolitan area size (POPULN): is given by data item q, (1050 thousand persons).

q. Metropolitan area rating (MAREA): using data items q through t in conjunction with Table B1 the metropolitan area rating is computed to be equal to 22.

The above two input items are punched on a single computer card in the format: F6.0, F4.0.

The computer time required to search for an optimum solution (equations 14 through 17) is approximately equal to (-10 + 0.075 IZMAX) seconds.

Output

The output of the computerized package for determining successful design criteria consists of three groups. The outputs are (a) the predicted demand, (b) the economics of the change of mode parking lot, and (c) the design criteria of the proposed parking facility. A sample output is given on page 105 for the inputs given in Figure 18. If it is not possible to provide an economical design, an alternate output is produced to indicate the fact (see Appendix F).

The predicted demand is measured in terms of park 'n ride vehicles, kiss 'n ride vehicles and percent occupancy of the change of mode parking facility. Also given is an estimate of the transit passengers that arrive at the station by passenger car.

The economics of the change of mode parking facility is defined by (a) the capital investment incurred to own and construct the parking lot, (b) the running costs of the facility operator, (c) the savings that accrue to the community from change of mode and per park 'n ride vehicle, and (d) the community benefits over and above the minimum acceptable rate of return. The capital recovery factor on the capital outlay is also given. In the hypothetical situation being investigated the capital recovery factor given corresponds to a 12 percent rate of return on investment.

** DEMAND **** DEMAND **** DEMAND **** DEMAND **** DEMAND ****

PARK AND RIDE = 685 VEHICLE /DAY

KISS AND RIDE = 516 VEHICLE /DAY

TRANSIT PASSENGERS = 1633 PASSENGERS /DAY

PERCENT OCCUPANCY = 94.5 PERCENT

** FEASIBILITY **** FEASIBILITY **** FEASIBILITY **** FEASIBIL

CAPITAL INVESTMENT = 3.06 DOLLARS /SQUARE FOOT

RUNNING COSTS = 36.6 DOLLAR /STALL-YEAR

COMMUNITY SAVING = .72 DOLLAR /VEHICLE-DAY

COMMUNITY BENEFITS = 44419 DOLLARS /YEAR

CRF ON INVESTMENT = .144

** CRITERIA **** CRITERIA **** CRITERIA **** CRITERIA **** CRI

FACILITY SIZE = 725 STALLS

KISS AND RIDE RATE = 8.0

ATTENDANTS RATE = 0.0

MAINTENANCE RATE = 0.0

PARKING FEE RATING = 3.0

The predicted demand, and the economics are based on the set of printed design characteristics rates. The results of the example are:

a. Develop 725 park 'n ride stalls out of a possible 800, for the park 'n ride demand.

b. Using Table B5 with a kiss 'n ride rate of 8.0, develop more than 6 percent of the facility for the kiss 'n ride demand.

c. Using Table B6 with an attendants rate of 0.0, do not employ any attendants for the parking facility.

d. Using Table B6 with a maintenance rate of 0.0, do not maintain the parking lot.

e. Using Table B7 with a parking fee rating of 3.0, charge a parking fee of 0.2-0.5 dollars per park 'n ride vehicle.

The above design characteristics maximize the benefits of the community, and therefore should be the successful design criteria for the hypothetical facility being investigated.

CHAPTER 8. CONCLUSION

The objective of this research was to study change of mode parking facilities, but mainly was to develop successful design criteria. The adopted computerized package appears to be an effective tool for determining successful design criteria of any change of mode parking facility in any medium sized or large U. S. city.

Summary

A survey was conducted to collect data on the demand placed upon, and the characteristics (location, transit, and design) of change of mode parking facilities. Ninety-three change of mode parking facilities in ten different cities were used in the study.

Data items were aggregated to form a much smaller number of super factors which were called ratings. The effect of these ratings - a measure of the location, transit and design characteristics of parking facilities - on the usage of change of mode parking facilities was studied by using the analysis of variance technique. These same ratings were used to develop a change of mode parking demand prediction equation, which was later tested with appropriate data and found to apply. Community savings that accrue from diverting an auto trip to the downtown into a change of mode trip are simulated. Land values and running costs of change of mode parking facilities are also determined.

The findings were combined to develop a computerized package capable of determining the economically optimal - from a community wide point of view - design characteristics of any change of mode parking facility. Estimates are provided of park 'n ride and kiss 'n ride demand, and of transit passengers arriving by car. Also provided are the capital investment and running costs of the parking facilities, along with estimates of the community savings, benefits and rate of return on investment in change of mode parking facilities.

The input required is within easy reach of any city transit or parking authority, and requires a very small cost to develop. The needed data consists mainly of the characteristics of the city and the transit system which the parking facility serves, and its maximum size and location. The output of the package is concise, and requires a minimal time to analyze.

Conclusions

Statistical evidence indicates that most of the developed characteristics' ratings are significant in affecting change of mode parking facility usage. An increase in the metropolitan area, facility reliability, and facility safety ratings causes a significant increase in the occupancy of change of mode parking facilities.

Because no control over the collected data could be exercised, no clear cut decision on the effect of the facility safety, facility flexibility and transit service ratings could be taken. The facility location rating was found to be insignificant in affecting the usage of parking facilities.

A study of the park 'n ride demand prediction equation would indicate that all of its independent terms contribute almost equally in estimating the demand. All of the independent terms are positively proportional to the park 'n ride demand. In other words, an increase in the value of any independent variable would result in an increase in the estimate of the demand.

The independent variables that predict the park 'n ride demand are the size of the facility, its flexibility, reliability and parking fee ratings, and the metropolitan area and transit service ratings associated with the change of mode parking facility. Four of the six ratings that measure the design characteristics of the parking facility are included in the prediction equation. This fact substantiates the method used in developing the ratings from the survey data. The facility safety, and physical quality ratings did not enter the prediction equation because of their correlation with other ratings already included. The fact that two-thirds of the demand estimate is due to parking facility design characteristics points up the importance of these characteristics. Many of the existing methods fail to include these characteristics.

The savings that accrue to a community from the use of change of mode parking are most sensitive to the location of the parking facility. The further from the downtown the change of mode takes place, the larger the unit savings. However, under this condition the transit service rating tends to decline because of the uneconomy of providing the same quality of service as that found closer in to the downtown. Also, facilities located far from the downtown are under suburban jurisdictions which do not possess and cannot raise the funds required for providing good quality parking facilities. The park 'n ride demand is thus reduced. The combination of facts thus suggests that the total community benefits would peak at a specific distance from the downtown, and would decline from there on.

The application from Chapter 7 shows that change of mode parking facilities can be economically feasible. However, an extensive change of mode parking development scheme does require large amounts of funds which are scarce in large metropolitan areas where the need to alleviate the parking condition is acute. Investing parking meters funds in a special fund, similar to the gas tax and the highway fund, for providing change of mode parking facilities has been proposed.

Recommendations for Further Research

The design criteria for change of mode parking facilities have been determined based on an economical optimization process. However, the economics of change of mode parking depends on the distances driven by the commuters from their homes to the parking facility. Although these distances have been estimated, it is felt that more data could be used to refine and substantiate the work done. This would entail collecting data regarding the origin of change of mode commuters in different cities and at many change of mode parking facilities. The cooperation of change of mode operators would be a necessity in distributing and collecting the required questionnaire forms.

The park 'n ride demand has been predicted by using super variables, herein called ratings, as the independent terms in a linear regression equation. Although the chosen demand prediction equation was found to apply when tested, it is felt that more work should be done in the development of the ratings so as to improve the prediction quality of the park 'n ride demand equation. The collected data could be used in a trial and error method to develop alternate ratings with which alternate park 'n ride demand prediction equations would be created. The different alternate prediction equations would then be tested against additional data from different facilities and sources.

The final and most important avenue for research is to use the computerized package resulting from this project to study the effects of the constraints on the design of change of mode parking facilities. The constraints on the design are mainly the metropolitan area, the transit system and the location of the parking facility within the metropolitan area. The results of such a research would be general recommendations for successful change of mode parking facility design criteria. No additional data need to be collected since the computerized design package provided by this project would be the simulation tool.

Attitudinal questionnaires in further research should be written using professional outside counseling. Also, the replies to surveys should be separated by waves and each wave would be tested against all other waves so as to ascertain that the inference space extends to the non-respondents. Once this is done, the data would be pooled for later analysis.

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APPENDIX A

SURVEY QUESTIONNAIRE

QUESTIONNAIRE

CHANGE OF MODE PARKING FACILITIES

Name of Facility ______________ Name: ______________

Name of Metropolitan Area ______________ Position: ______________

Name of Political Jurisdiction in which facility is located ______________ Address: ______________

Date: ______________

A-DEMAND

1. What is the average number of park&ride vehicles that use the facility, by year, since the beginning of parking service? (veh/day) SELECT ONE YEAR (DATE ______) FOR WHICH YOU ARE SUPPLYING ANSWERS TO THE QUESTIONS THAT FOLLOW.	____ 1st year ____ Date ____ 2nd year ____ 3rd year ____ 4th year ____ 5th year ____ 6th year ____ 7th year ____ 8th year ____ 9th year ____ 10th year ____ present
2. What is the average number of park&ride vehicles that use the facility?	______ (veh/day)
3. What is the average number of kiss&ride vehicles that use the facility?	______ (veh/day)
4. What is the average number of transit passengers that transfer from atuo?	______ (persons/day)
5. What is the average number of transit passengers that board at facility?	______ (persons/day)
6. What is the average number of transit passengers that board at facility, by day of the week? (persons/day)	____ Monday ____ Tuesday ____ Wednesday ____ Thursday ____ Friday ____ Saturday ____ Sunday
7. What is the proportion of morning peak park&ride vehicle arrivals to total vehicle arrivals within an average day?	______ %
8. Is there any indication that a substantial number of transit passengers park outside the parking facility? If answer is yes, please give proportion of outside to inside parked vehicles.	O ..... Yes O ..... No ______ %

B. TRANSIT SERVICE

1. What is the type of the transit system being served by parking facility?	○ ..... bus ○ ..... rail
2. What is the average headway between transit vehicles serving facility during peak periods?	________ min.
3. What is the transit fare from facility to downtown of metropolitan area?	________ cents
4. What is the overall travel time by transit, from facility to downtown of metropolitan area?	________ min.
5. What is the proportion of jobs in the downtown area (as compared to other cities) that is reached, within acceptable walking distance, by the transit system being transferred to?	○ ....high ○ ..... average ○ ....low

C. PHYSICAL CHARACTERISTICS

1. What is the lighting condition at the parking facility?	○..... good ○..... adequate ○..... poor ○.......... none
2. Is the facility well enclosed with adequate entrances and exits?	○..... yes ○..... fair ○..... no _______ exits _______ entrances
3. Under what category does the transit terminal fall?	○...... Luxurious building ○....... adequate building ○...... sheltered platform ○........... platform only
4. Under what category does the facility pavement fall?	○ ..... well paved with markings ○ .... treated surface ○ .... gravel
5. What is the average walking distance from facility parked cars to transit platform?	________ feet

D-OPERATIONAL CHARACTERISTICS

1. Does the facility include any kiss & ride stalls? If answer is yes, please give number.	○..... yes ○...... no ______ stalls
2. Does the facility have any bus berths? If answer is yes, please give number of regular buses that stop at these berths.	○..... yes ○...... no ____ buses/peak hour ____ berths
3. How many hours within the day is the facility operational?	______ hours
4. How many days within the week is the facility operational?	______ days
5. How would you classify the maintenance level provided at the facility?	○..... Good ○..... Adequate ○..... Poor ○......... None
6. What is the parking charge at facility?	____ cents/hour ____ dollars/day
7. How many park&ride stalls are there at the facility?	______ stalls
8. Does the facility have any attendants? If answer is yes, please give number of attendants.	○..... yes ○..... no ______ attendants
9. Is the parking facility operated for the sole use of the transfer passengers? If answer is no, please indicate the nature of the other usages.	○..... yes ○..... no ______ ______

E-LOCATION OF FACILITY

1. What is the major land use type in which the parking facility is located?	○..... Resd'l ○........... Ind'l ○..... Res+Ind ○.......... Rs+Com ○..... Comm'l ○..... Rs+Ind+Com
2. What is the aerial distance from facility to downtown center of metropolitan area?	______ miles
3. What is the aerial distance from facility to nearest competitive facility?	______ miles
4. What is the aerial distance from facility to next lower transit fare zone?	______ miles

5. What is the distance from main facility entrance to major highway arterial access?	______ blocks
6. What is the name of this major highway arterial access?	______
7. What is the ADT of this major highway arterial access?	______ Vpd
8. How many lanes does this major highway arterial access have?	______ lanes
9. How visible is the facility from its major highway arterial access?	○ .... quite visible ○ .... slightly visible ○ .... Info signs are posted ○ .... not visible

F-GENERALITIES

1. Who owns the parking facility?	______
2. Who operates the facility?	______
3. Are transfers between transit systems and/or lines allowed in metropolitan area served? If answer is yes, please give the charge for such transfers.	○ ..... yes ○ ..... no ______ cents
4. Does the transit system being transferred to at the facility have more than one fare zone? If answer is yes, please give number.	○ ..... yes ○ ..... no ______ Fare zones
5. What is the average overall travel speed within metropolitan area, by type of transit?	____ Mph ____ Transit type ____ Mph ____ Transit type ____ Mph ____ Transit type
6. How would you classify the parking condition in the downtown of metropolitan area served by facility?	○ .... Intolerable ○ .... Problematic ○ .... Worrisome ○ .... little to worry
7. At what distance from downtown, along arterial corridors, would you estimate the traffic to become heavily congested during the morning peak period?	______ miles

APPENDIX B

AGGREGATE VARIABLES, DEVELOPMENT TECHNIQUE

TABLE B1. METROPOLITAN AREA RATING*

Representative Transit Speed In Metropolitan Area		Condition of Parking In CBD		Distance From CBD Where Heavy Congestion Starts		Metropolitan Area Population	
Levels (mph)	Rate	Levels	Rate	Levels (mi.)	Rate	Levels (10^6 persons)	Rate
$20<s$	10	Intolerable	5	$8<d$	8	$2.5<p$	9
$15<s\leq 20$	6	Problematic	3	$5<d\leq 8$	6	$1.0<p\leq 2.5$	6
$10<s\leq 15$	4	Worrisome	2	$3<d\leq 5$	4	$0.5<p\leq 1.0$	3
$s\leq 10$	2	No Worry	1	$d\leq 3$	2	$p\leq 0.5$	1

*Metropolitan area rating = Transit speed + CBD parking congestion

+ Radial highway congestion

+ Metropolitan area population

TABLE B2. FACILITY LOCATION RATING*

Distance to Lower Fare Zone		Distance to Nearest Competitive Facility		Distance to Highway Access		Width of Highway Access	
Levels(mi.)	Rate	Levels(mi.)	Rate	Levels(blocks)	Rate	Levels(lanes)	Rate
None or $5<d$	5	None or $5<d$	3	$d<2$	3	$L>4$	6
$2<d\leq5$	3	$2<d\leq5$	2	$2\leq d<5$	2	$L=4$	3
$1<d\leq2$	1	$1<d\leq2$	1	$5\leq d$	1	$L<4$	1
$d\leq1$	0	$d\leq1$	0				

*Facility Location rating = (Distance to fare zone x Distance to Competition)

+ (Distance to access x Width of access)

+ Visibility from access + Distance to CBD

+ (Surrounding land use type + Residential density)

TABLE B2. Cont.

Visibility of Facility From Access		Distance From Facility to CBD		Surrounding Land Use Type		Surrounding* Residential Density	
Levels	Rate	Levels(mi.)	Rate	Levels	Rate	Levels($\frac{10^3 per.}{sq.mi.}$)	Rate
Quite Visible	3	16<d	10	Residential	6	22<d	7
Slightly Visible	2	12<d≤16	8	Res'l-Com'l	4	16<d≤22	5
Info. Signs are posted	1	8<d≤12	6	Commercial	3	10<d≤16	3
Not Visible	0	4<d≤8	4	Res'l-Ind'l	2	4<d≤10	1
		2<d≤4	2	Res'l-Ind'l-Com'l	1	d≤4	0
		d≤2	0	Industrial	0		

*See Figure B1

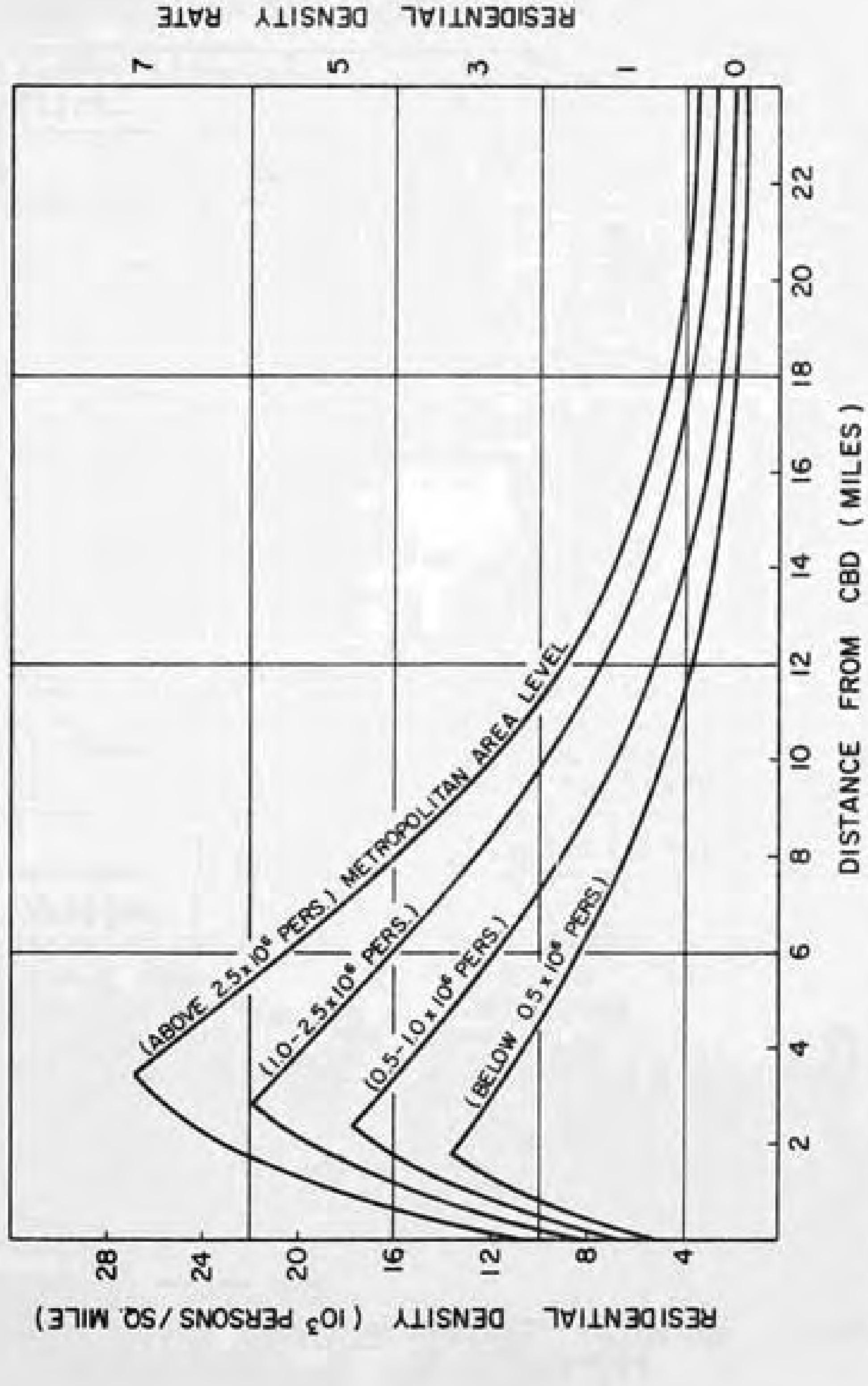

FIGURE B1 RESIDENTIAL DENSITY AS A FUNCTION OF LOCATION WITHIN CITY, AND METROPOLITAN SIZE LEVEL

TABLE B3. FACILITY SAFETY RATING*

Condition of Lighting In Facility		Availability of Enclosures And Number Of Gates	
Levels	Rate	Levels, $g = (\frac{\text{gates}}{200 \text{ stalls}})$	Rate
Good	3	Yes, $g > 1$	3
Poor	2	Yes, $g \leq 1$	2
Fair	1	Fairly enclosed	1
None	0	None	0

TABLE B4. PHYSICAL QUALITY RATING OF FACILITY**

Pavement Type of Facility		Average Walking Distance From Facility to Station	
Levels	Rate	Levels (feet)	Rate
Paved, Marking & Landscaping	8	$d < 300$	4
Paved & Marking	6	$300 \leq d < 500$	3
Treated Surface	4	$500 \leq d < 700$	2
Gravel	2	$700 \leq d$	1

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* Facility Safety rating = Facility lighting + Availability of Enclosures

**Physical Quality rating = Pavement type + Walking distance

TABLE B5. RATING OF FACILITY FLEXIBILITY*

Agency Type of Facility Owner		Agency Type of Facility Operator	
Levels	Rate	Levels	Rate
Transportation and/or Planning either public or private	2	Same as Transit Operator	2
Other	1	Different from Transit Operator	0

Proportion of Kiss & Ride Stalls to Total Stalls in Facility		Availability of Connecting Bus Lines	
Levels (percent)	Rate	Levels	Rate
6.00<p	8	Yes	10
3.00<p≤6.00	4.5	No	0
1.00<p≤3.00	2.0		
0.00<p≤1.00	0.5		
p=0.00	0.0		

*Flexibility rating = (Agency type of owner x Agency type of operator) + Availability of bus berths + Proportion of kiss 'n ride stalls

TABLE B6. RATING OF FACILITY RELIABILITY*

Days of Facility Operation		Hours of Facility Operation		Availability and Number of Attendants		Maintenance Quality	
Levels (Days/week)	Rate	Levels (hr/day)	Rate	Levels $(\frac{\text{attendants}}{\text{200 stalls}})$	Rate	Levels	Rate
$d=7$	2.0	$20<h$	2.0	Yes, $1.5<a$	10	Good	5.0
$d=6$	1.0	$12\leq h\leq 20$	1.0	Yes, $0.5<a\leq 1.5$	5	Adequate	2.5
$d\leq 5$	0.4	$h<12$	0.4	Yes, $a\leq 0.5$	2	Poor	1.0
				No	0	None	0

*Reliability rating = Days of operation + hours of operation + Availability of attendants + Maintenance quality

TABLE B7. RATING OF FACILITY PARKING FEE

Facility Parking Fee	
Level ($/day)	Rate
f=0.00	6
0.00<f≤0.20	4
0.20<f≤0.50	3
0.50<f≤1.00	2
1.00<f	1

TABLE B8. RATING FOR YEARS FROM START

(Polling Date - Start of Operation Date)	
Levels (years)	Rate
y≤1	0
2≤y≤6	1
7≤y	2

APPENDIX C

AGGREGATE VARIABLES, DATA

TABLE CI SUMMARY OF SURVEY DATA AND FACTORS AFFECTING PARKING DEMAND

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYSICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
MILWAUKEE	26.7	300	64	0	0	32	14	30	2	10	8.0	3.3	6
	52.3	300	66	0	1	32	14	30	2	10	8.0	3.3	6
	60.0	300	68	0	1	31	16	29	2	10	8.0	3.3	6
	56.7	300	70	0	1	25	16	37	2	10	8.0	3.3	6
	79.3	150	66	0	0	34	14	49	2	10	8.0	3.3	6
	83.3	150	68	0	1	34	14	49	2	10	8.0	3.3	6
	76.7	150	70	0	1	34	14	49	2	10	8.0	3.3	6
	76.0	50	70	0	0	32	16	38	2	10	8.0	3.3	6
	48.0	100	68	0	0	32	16	36	2	10	8.0	3.3	6
	69.0	100	70	0	1	25	18	44	2	10	8.0	3.3	6
	39.0	100	68	0	0	31	16	34	2	10	8.0	3.3	6
	52.0	100	70	0	1	31	18	44	2	10	8.0	3.3	6
	30.0	100	70	0	0	25	16	44	2	10	8.0	3.3	6
BALTIMORE	24.0	100	66	0	0	66	17	20	6	10	8.0	5.8	6
	66.0	100	68	0	1	66	17	24	6	10	8.0	5.8	6
	77.0	100	70	0	1	66	17	24	6	10	8.0	5.8	6
WASHINGTON	24.0	50	65	0	0	23	19	28	1	6	0.0	3.3	6
	42.5	200	70	0	1	40	22	36	1	10	0.0	3.3	6
	75.0	100	70	0	0	39	20	36	1	10	0.0	3.3	6
	25.0	100	70	0	0	22	22	37	1	10	0.0	3.3	6
	8.7	150	63	0	0	14	17	43	1	10	2.0	3.3	6
	3.3	150	62	0	0	23	17	40	1	10	2.0	3.3	6
	98.4	625	64	0	2	19	15	52	5	10	0.0	7.8	6
	109.8	625	68	0	2	19	18	64	5	10	0.0	7.8	6
	76.9	290	64	0	1	20	15	49	6	10	0.0	10.8	6

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYSICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
WASHINGTON (continued)	73.1	290	68	0	2	20	18	61	6	10	0.0	10.8	6
	80.0	250	64	0	2	22	15	49	4	8	0.0	10.8	6
	100.4	250	68	0	2	21	18	49	4	8	0.0	10.8	6
	76.9	260	66	0	1	20	18	43	5	10	0.0	10.8	6
	55.4	471	68	0	2	20	18	43	5	10	0.0	7.8	6
NEW YORK	125.8	1325	65	0	2	41	28	55	5	10	4.0	12.0	3
	131.7	1450	70	0	2	41	28	55	5	10	4.0	12.0	2
	74.9	1148	64	1	2	36	28	33	5	8	8.0	9.0	2
	95.8	1148	67	1	2	34	28	33	5	8	8.0	9.0	2
	100.0	114	64	1	2	25	28	27	5	9	0.0	9.0	2
	100.9	114	67	1	2	25	28	27	5	9	0.0	9.0	2
CHICAGO	92.4	448	69	1	2	99	30	31	6	10	0.5	5.5	3
	184.5	290	69	1	2	36	26	23	2	9	0.0	9.0	3
	108.2	510	66	1	1	33	30	13	4	8	0.0	9.0	3
	189.2	510	69	1	2	33	30	13	4	8	0.0	9.0	3
	93.4	803	68	1	2	84	30	28	2	8	8.0	9.0	3
	227.0	378	69	1	2	83	28	22	4	9	0.0	9.0	3
	84.1	315	66	1	1	50	28	22	2	10	0.0	9.0	3
	66.8	757	66	1	1	87	28	19	5	10	2.0	9.0	3
	75.4	757	69	1	2	86	28	19	5	10	2.0	9.0	3
	127.1	377	69	1	2	51	28	23	5	7	0.0	6.5	3
	49.8	201	66	1	1	69	30	28	5	8	0.0	5.5	3
	180.8	255	69	1	2	68	30	19	5	8	0.0	10.5	2
	102.7	224	65	1	1	99	26	18	5	8	0.0	9.0	3
	72.3	224	70	1	2	98	26	18	5	9	0.0	9.0	3

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYS-ICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
CHICAGO (continued)	72.3	242	65	1	1	99	26	18	5	8	0.0	9.0	3
	48.3	242	70	1	2	98	26	18	5	8	0.0	9.0	3
	134.9	149	65	1	1	99	26	42	6	9	10.0	9.0	3
	157.7	149	70	1	2	98	26	42	6	9	10.0	9.0	3
	130.1	146	65	1	1	99	26	42	6	8	0.0	9.0	3
	126.0	146	70	1	2	98	26	42	6	8	0.0	9.0	3
	119.9	211	65	1	1	45	28	51	6	9	0.0	9.0	3
	102.4	211	70	1	2	43	28	51	6	9	0.0	9.0	3
	192.9	350	65	1	2	97	26	59	6	9	8.0	14.0	3
	186.9	412	70	1	2	96	26	56	6	9	8.0	9.0	3
	115.3	72	65	1	1	97	26	59	6	7	0.0	9.0	3
	115.3	72	70	1	2	96	24	56	6	7	0.0	9.0	3
	143.9	310	65	1	2	61	26	43	4	5	0.0	6.5	6
	125.5	310	70	1	2	59	26	43	4	5	0.0	6.5	6
	162.0	50	65	1	0	61	26	43	5	5	0.0	6.5	3
	170.0	50	70	1	1	60	26	43	5	5	0.0	6.5	3
	133.6	235	70	1	0	64	30	19	5	10	18.0	9.0	3
	102.8	535	65	1	0	97	29	22	5	9	14.5	7.0	3
	105.2	535	70	1	1	96	29	22	5	9	14.5	7.0	3
PITTSBURGH	60.0	250	70	1	2	21	19	20	3	6	10.0	6.5	6
	83.6	275	70	1	2	41	19	41	5	10	0.0	11.0	3
	97.8	90	70	1	2	41	19	32	2	8	4.0	6.5	6
	100.0	120	70	1	2	41	19	40	3	6	0.0	6.5	3
	67.6	170	70	1	2	41	19	41	6	10	0.0	14.0	6

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYS-ICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
CLEVELAND	101.4	740	58	1	1	39	22	35	5	8	12.0	8.0	6
	100.0	870	61	1	1	39	23	35	5	8	12.0	8.0	6
	100.0	708	65	1	2	39	23	35	4	8	12.0	5.5	6
	88.3	708	69	1	2	38	25	35	3	8	12.0	4.0	6
	100.0	145	58	1	1	39	22	28	6	10	10.0	8.0	6
	100.0	145	61	1	1	38	23	28	4	10	10.0	8.0	6
	100.0	145	65	1	2	38	23	28	5	10	10.0	5.5	6
	100.0	137	69	1	2	38	25	28	4	10	10.0	4.0	6
	100.0	50	58	1	1	37	22	15	6	10	0.0	8.0	6
	100.0	50	61	1	1	36	23	15	5	10	0.0	8.0	6
	100.0	50	65	1	2	24	23	15	5	10	0.0	5.5	6
	100.0	50	69	1	2	24	25	30	5	10	0.0	4.0	6
	83.3	300	58	1	1	38	22	41	5	10	14.5	8.0	6
	83.3	300	61	1	1	38	23	41	4	10	14.5	8.0	6
	83.3	300	65	1	2	37	23	41	4	10	14.5	5.5	6
	83.3	300	69	1	2	37	25	41	3	10	14.5	4.0	6
	90.0	500	58	1	1	38	22	25	5	10	14.5	8.0	6
	80.0	500	61	1	1	38	23	25	4	10	14.5	8.0	6
	70.0	500	65	1	2	38	23	25	4	10	14.5	5.5	6
	55.0	500	69	1	2	37	25	25	4	10	14.5	4.0	6
	100.0	676	58	1	0	38	22	15	5	10	12.0	8.0	6
	105.0	1175	61	1	1	38	23	15	5	10	12.0	8.0	6
	105.0	1175	65	1	2	38	23	15	4	10	12.0	5.5	6
	51.1	1175	69	1	2	37	25	15	4	10	12.0	5.5	6
	100.0	1500	58	1	0	39	22	18	5	9	14.5	8.0	6
	97.5	2000	61	1	1	39	23	18	5	9	12.0	8.0	6
	97.5	2000	65	1	2	38	23	18	4	9	12.0	8.0	6

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYS-ICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
CLEVELAND (continued)	42.5	2000	69	1	2	38	25	18	3	10	12.0	5.5	6
	100.0	1000	69	1	0	39	25	29	5	10	12.0	5.5	6
	80.0	1000	69	1	0	38	25	27	5	10	12.0	5.5	6
	98.1	570	65	1	2	37	22	44	2	9	4.5	4.0	6
	101.3	790	70	1	2	36	21	40	4	8	2.0	5.5	6
	107.4	95	65	1	2	37	22	47	4	8	0.0	4.0	6
	104.2	120	70	1	2	36	21	47	4	10	0.0	5.5	6
	111.1	316	65	1	2	37	22	28	3	8	0.0	5.5	6
	109.0	367	70	1	2	36	21	28	3	8	0.0	8.0	6
	109.8	92	65	1	2	39	22	45	1	6	2.0	4.0	6
	100.0	105	70	1	2	38	21	45	1	10	0.5	5.5	6
	98.6	72	65	1	2	37	22	45	1	6	0.0	3.0	6
	104.2	72	70	1	2	36	22	45	1	10	0.0	5.5	6
	104.6	108	65	1	2	37	22	45	1	6	0.0	3.0	6
	122.9	131	70	1	2	37	22	45	1	10	0.0	5.5	6
	140.7	118	65	1	2	24	22	37	1	8	0.0	5.5	6
	84.7	118	70	1	2	35	22	25	3	8	0.0	4.0	6
BOSTON	23.6	1600	70	0	1	67	26	35	5	9	10.5	6.4	4
	120.3	59	70	0	1	27	26	35	5	10	8.0	9.0	3
	19.7	1600	63	1	1	63	22	20	5	9	10.5	8.0	3
	37.8	1600	65	1	1	63	22	20	5	9	10.5	8.0	4
	70.5	390	63	1	1	61	22	36	5	10	14.5	4.5	3
	53.8	390	65	1	1	61	22	36	5	10	14.5	4.5	3
	51.3	390	70	1	2	60	22	36	5	10	14.5	9.5	3
	100.0	42	63	1	1	60	22	24	5	10	0.0	5.5	3
	100.0	42	65	1	1	60	22	24	5	10	0.0	5.5	3

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYSICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
BOSTON (continued)	95.2	42	70	1	2	60	22	24	5	10	0.0	5.5	3
	100.0	57	63	1	1	60	22	33	4	10	0.0	4.0	3
	100.0	57	65	1	1	60	22	33	4	10	0.0	4.0	3
	70.2	57	70	1	2	60	22	33	4	10	0.0	14.0	3
	100.0	55	63	1	1	42	26	40	4	9	0.0	4.0	3
	100.0	55	65	1	1	42	26	40	4	9	0.0	4.0	3
	100.0	55	70	1	2	41	22	46	4	9	0.0	14.0	3
	58.8	160	63	1	1	41	22	42	4	10	0.0	4.0	3
	94.4	160	65	1	1	41	22	37	4	10	0.0	4.0	3
	65.8	480	63	1	2	97	22	37	4	9	12.0	3.0	3
	67.1	480	65	1	2	82	22	37	4	9	12.0	3.0	3
	60.0	500	70	1	2	81	22	37	4	9	12.0	5.0	2
	62.9	175	63	1	2	82	22	36	4	9	12.0	3.0	3
	71.4	175	65	1	2	82	22	36	4	9	12.0	3.0	3
	45.5	220	70	1	2	81	22	36	3	9	12.0	8.0	2
	29.5	210	63	1	2	51	22	52	2	8	0.5	3.0	3
	86.2	210	65	1	2	51	22	52	2	8	0.5	3.0	4
	83.3	210	70	1	2	51	22	51	2	8	0.5	8.0	3
	29.2	120	63	1	2	51	22	35	5	9	0.0	3.0	3
	94.2	120	65	1	2	51	22	35	5	9	0.0	3.0	4
	58.3	120	70	1	2	50	22	35	5	9	0.0	13.0	3
	50.0	260	63	1	2	50	22	52	5	9	14.5	4.0	3
	57.7	260	65	1	2	50	22	52	5	9	14.5	4.0	3
	72.7	454	70	1	2	50	22	52	5	9	12.0	6.0	2
	31.2	500	63	1	2	52	22	25	5	9	10.0	4.0	3
	74.0	500	65	1	2	52	22	25	5	9	10.0	4.0	4
	46.3	341	70	1	2	51	22	25	5	9	10.0	9.0	2

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYS-ICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
BOSTON (continued)	62.3	220	63	1	2	52	22	30	3	9	100	4.0	3
	81.8	220	65	1	2	52	22	30	3	9	100	4.0	3
	100.0	200	70	1	2	52	22	30	3	9	10.0	9.0	3
	100.0	32	63	1	2	52	22	22	4	10	0.0	3.0	3
	100.0	32	65	1	2	52	22	22	4	10	0.0	3.0	3
	100.0	20	70	1	2	52	22	22	4	10	0.0	130	3
	30.9	320	63	1	2	51	22	40	2	7	0.0	4.5	3
	110.0	320	65	1	2	51	22	40	2	7	0.0	4.5	4
	68.8	320	70	1	2	52	22	40	2	7	0.0	9.5	3
	81.7	60	63	0	2	17	22	46	4	8	0.0	4.0	3
	91.7	60	65	0	2	17	22	46	3	8	0.0	4.0	3
	110.0	60	70	0	2	17	22	46	3	8	0.0	4.0	3
	88.0	460	63	1	2	36	22	19	5	7	100	7.0	3
	96.1	460	65	1	2	36	22	31	5	7	10.0	7.0	3
	110.0	425	70	1	2	35	22	31	5	7	10.0	7.0	2
	100.9	115	63	1	2	36	22	6	5	6	10.0	3.0	3
	110.4	115	65	1	2	36	22	6	5	6	10.0	3.0	3
	110.1	79	70	1	2	37	22	6	5	6	10.0	3.0	2
	86.0	200	63	1	2	37	22	31	2	9	12.0	3.0	3
	70.5	200	65	1	2	37	22	31	2	9	12.0	3.0	3
	82.5	200	70	1	2	37	22	31	2	9	12.0	3.0	2
	100.8	360	63	1	2	19	22	12	2	9	10.0	5.5	3
	88.1	360	65	1	2	19	22	12	2	9	10.0	5.5	3
	110.1	358	70	1	2	19	22	12	2	9	10.0	105	2

TABLE CI Continued

METROPOLITAN AREA	FACILITY PERCENT USAGE	FACILITY SIZE (Stalls)	FACILITY POLLING DATE (Year)	TYPE OF TRANSIT RATING	FACILITY YEARS FROM START RATING	TRANSIT SERVICE RATING	METROPOLITAN AREA RATING	FACILITY LOCATION RATING	FACILITY SAFETY RATING	FACILITY PHYSICAL QUALITY RATING	FACILITY FLEXIBILITY RATING	FACILITY RELIABILITY RATING	FACILITY PARKING FEE RATING
PHILADELPHIA	157.5	40	70	1	2	61	28	22	6	10	0.0	9.0	6
	260.0	40	70	1	2	43	28	37	4	10	0.0	9.0	6
	94.7	190	70	1	2	95	28	38	6	6	0.0	6.5	6
	57.1	35	70	1	2	59	28	52	5	10	0.0	6.5	6
	90.9	110	70	1	2	95	28	39	6	10	0.0	6.5	6
	180.0	45	70	1	2	96	28	26	5	10	10.0	6.5	6
TORONTO	214.0	93	65	1	2	46	22	34	6	7	0.0	17.0	2
	238.7	93	70	1	2	46	22	34	6	7	0.0	17.0	2
	39.8	1416	70	1	1	48	26	31	5	7	0.0	9.0	3
	190.1	152	70	1	1	48	26	31	6	10	0.0	12.0	2
	70.3	438	70	1	1	48	26	46	5	10	0.0	9.0	3
	130.4	582	70	1	1	48	26	49	5	10	0.0	9.0	3
MINIMUM	3.3	32	58	0	0	14	14	6	1	6	0.0	3.0	2
MAXIMUM	260.0	2000	70	1	2	99	30	64	6	10	18.0	17.0	6

APPENDIX D

TRAVEL AND RELATED COSTS

TABLE D1. COST ITEMS FOR VEHICULAR OPERATION

Name	Cost ($/veh-mile)
Time Items:	0.0724
Licenses, depreciation & Vestcharge	0.0339
Insurance	0.0172
Garage, parking & tolls	0.0180
Property taxes	0.0033
Mileage Items:	0.0465
Engine oil	0.0016
Gasoline	0.0253
Maintenance	0.0155
Tires	0.0041

TABLE D2. VEHICLE OPERATION COSTS, BY HIGHWAY TYPE

Highway Type	Operating Cost, Mileage Items ($/veh-mile)	Total Operating Cost ($/veh-mile)
CBD Street	0.0698	0.1422
Local Street	0.0557	0.1281
Arterial Highway	0.0506	0.1230
Expressway	0.0404	0.1128

TABLE D3. POLLUTANTS COST, BY HIGHWAY TYPE

Highway Type	Emissions (lb/veh-mile)	Cost ($/veh-mile)
CBD Streets	0.545	0.0230
Local Streets	0.355	0.0150
Arterial Highways	0.292	0.0120
Expressways	0.152	0.0060

TABLE D4. ACCIDENTS COST, BY HIGHWAY TYPE

Highway Type	Accidents Rate (10^8/veh-miles)	Accidents Cost ($/veh-mile)
CBD Street	493	0.0072
Local Street	513	0.0074
Arterial Highway	340	0.0049
Expressway	160	0.0023

TABLE D5. TRAVEL TIME COST, BY HIGHWAY TYPE

Highway Type	Average Travel Speed (mph)	Cost of Time ($/veh-mile)
CBD Street	8	0.187
Local Street	15	0.100
Arterial Highway	19	0.081
Expressway	32	0.046

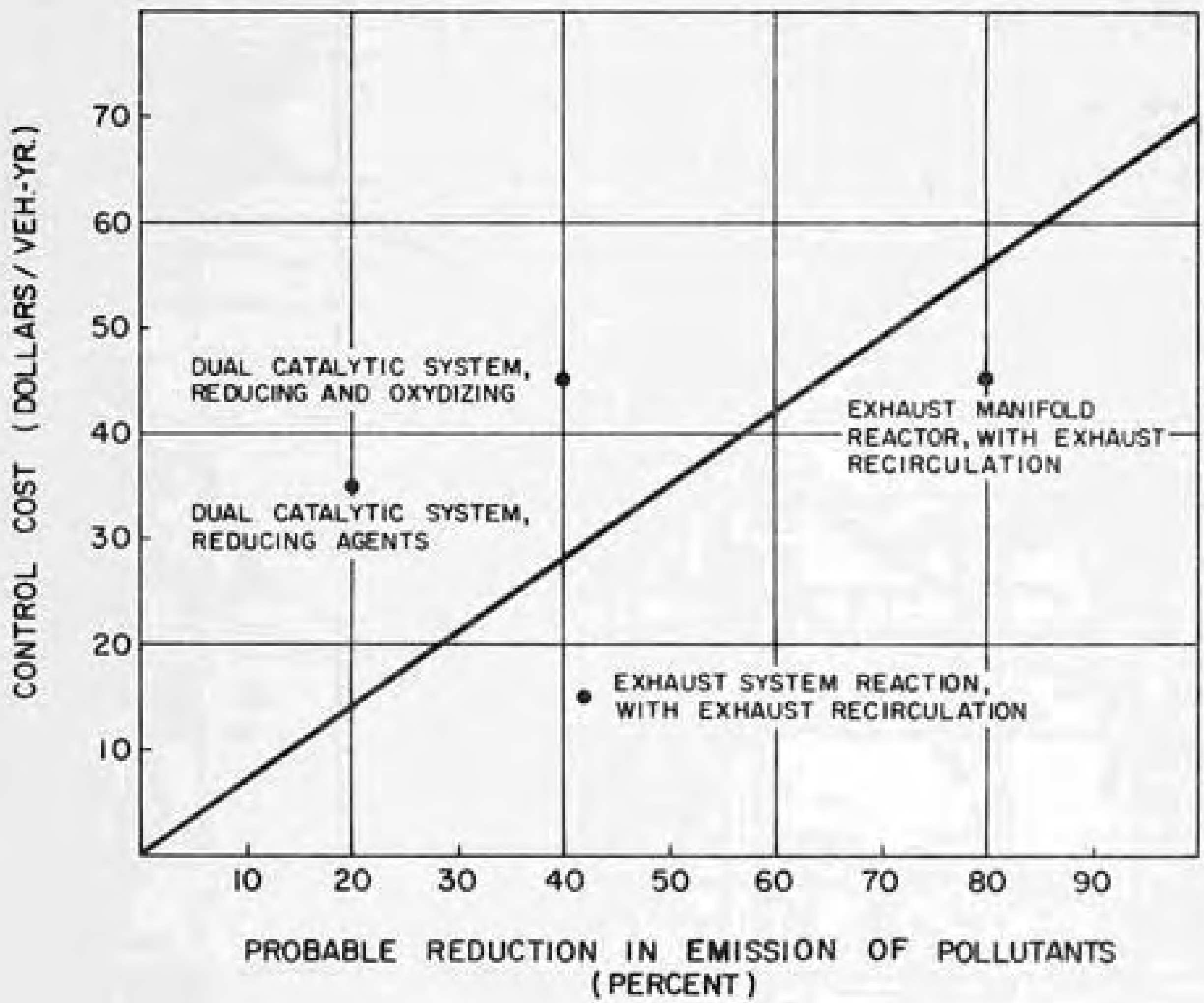


FIGURE D1 CONTROL COST OF PROBABLE REDUCTION IN EMISSION OF POLLUTANTS (35)

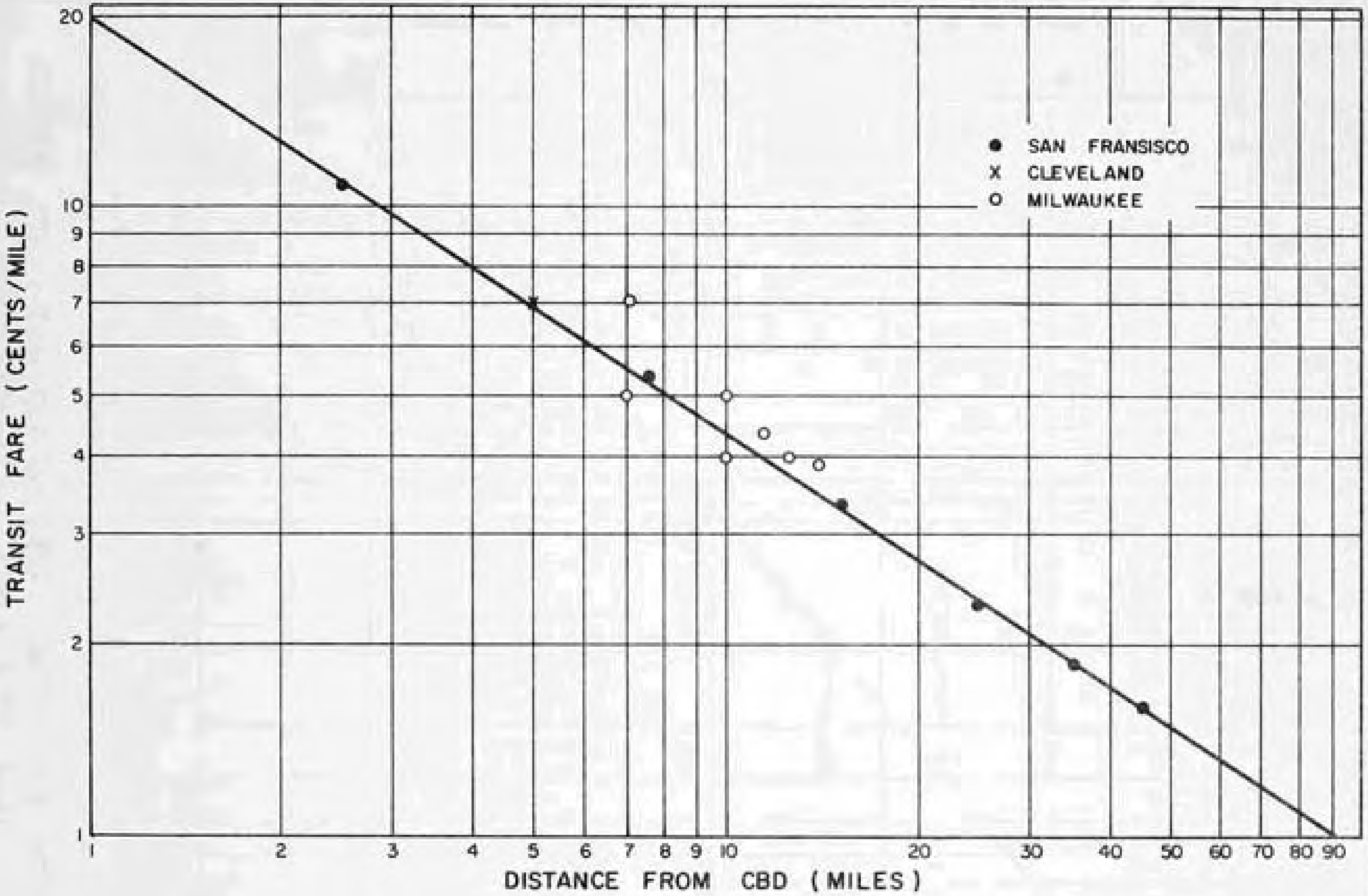


FIGURE D2 TRANSIT FARE, TO AND FROM CBD (5,18,19)

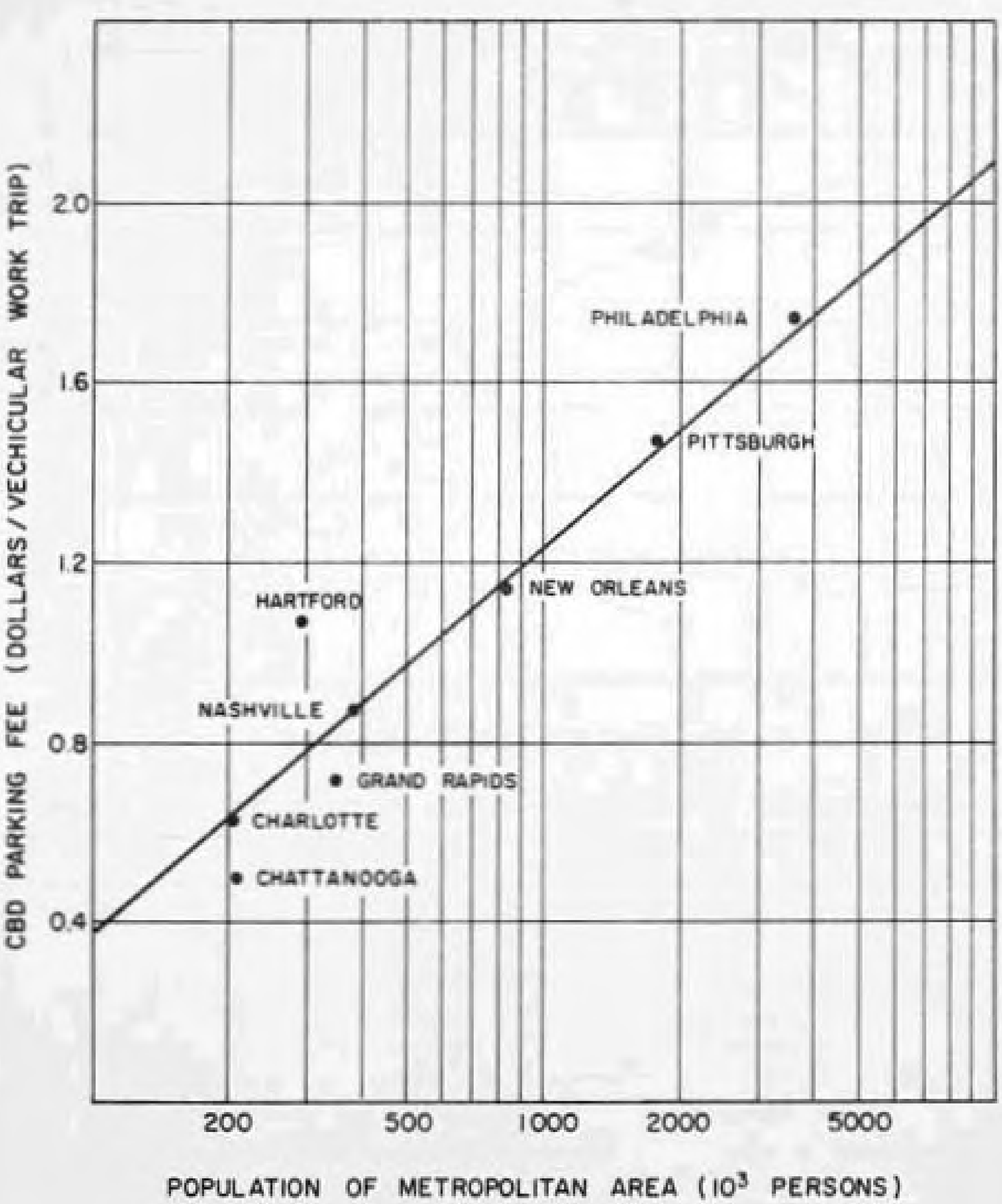


FIGURE D3 VARIATION OF CBD PARKING FEE WITH METROPOLITAN AREA SIZE (42)

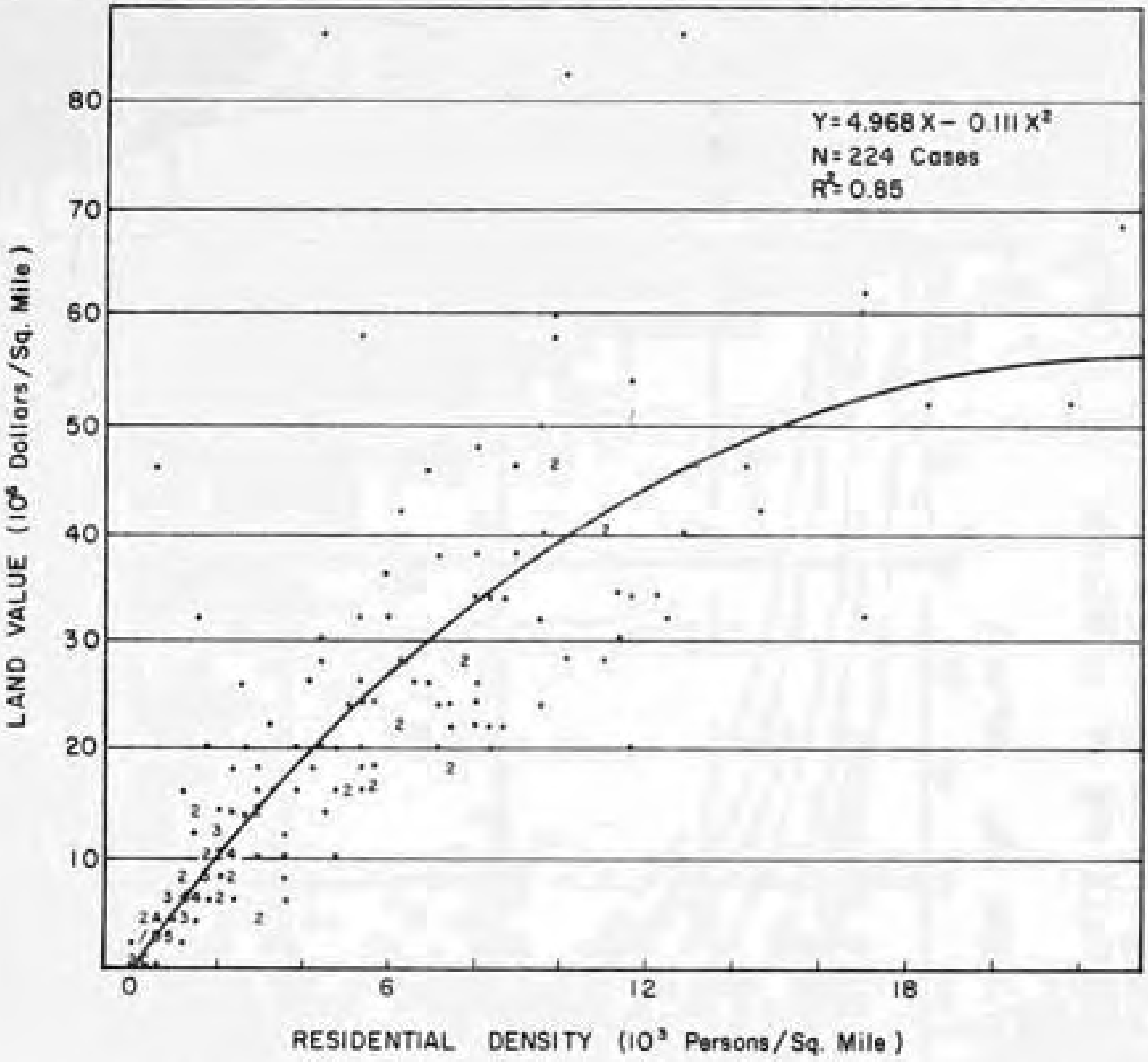


FIGURE D4 LAND VALUE VERSUS RESIDENTIAL DENSITY (44)

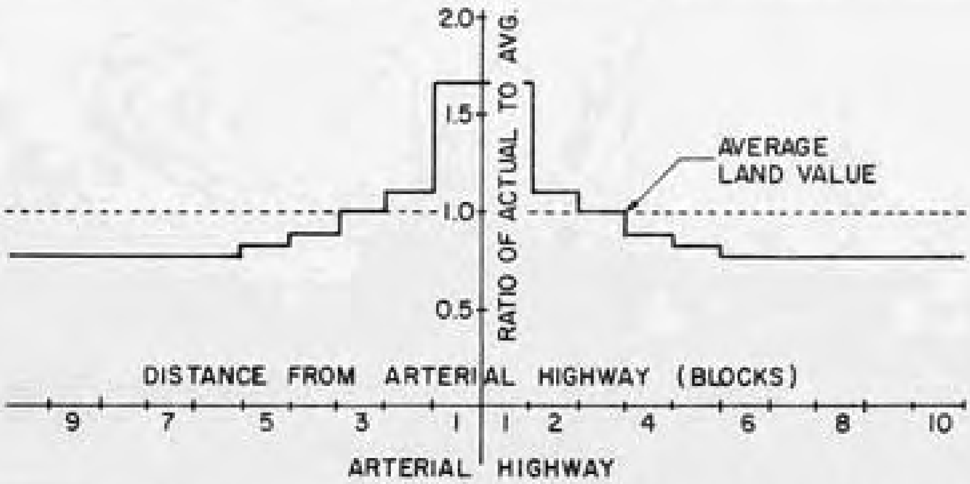


FIGURE D5 VARIATION OF LAND VALUE WITH DISTANCE FROM HIGHWAY (45)

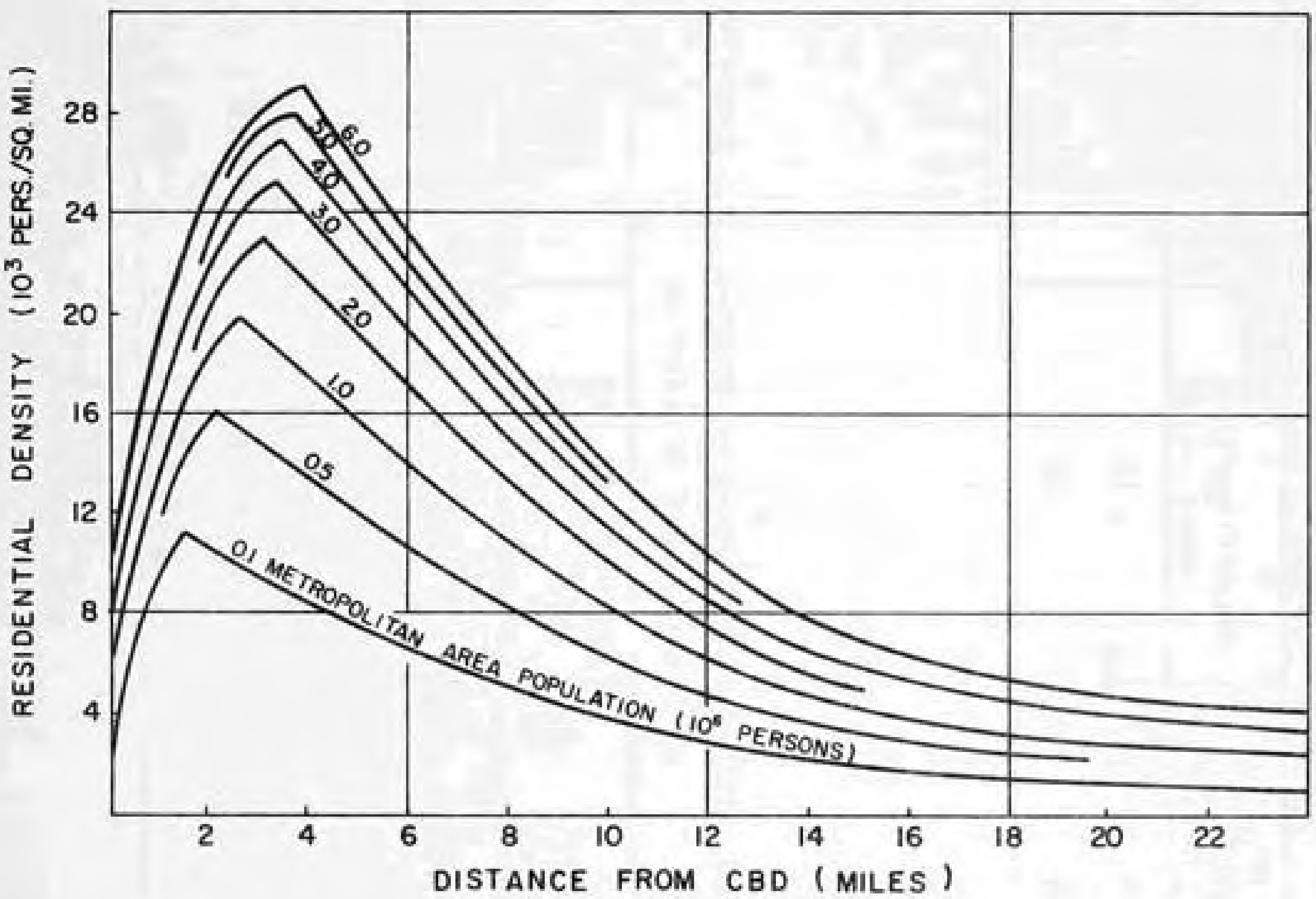


FIGURE D6 RESIDENTIAL DENSITY AS A FUNCTION OF LOCATION WITHIN CITY, AND METROPOLITAN AREA SIZE (46)

TABLE D6. TRAVEL TIME COST, BY TRANSIT TYPE

Transit Type	Average Travel Speed (mph	Cost of Time ($/passenger-mile)
Express Bus	21	0.0590
New Rapid Rail	38	0.0420

TABLE D7. CHANGE OF MODE TERMINAL TIME COST, BY TYPE OF TRANSIT

Transit Type	One Way Average Terminal Time (minutes)	Cost of Time ($/commuter)
Rail:		
Kiss & Ride	6.5	0.1355
Park & Ride	7.5	0.1563
Bus:		
Kiss & Ride	10.0	0.2085
Park & Ride	11.0	0.2292

APPENDIX E

COMMUNITY SAVINGS, SIMULATION PROGRAM

```
      PROGRAM MAIN(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
     1TAPE7=PUNCH)
C     ==================================================================
C     ==================================================================
C
C
C     THIS PROGRAM SIMULATES THE SAVINGS THAT ACCRUE TO A COMMU
C     NITY FROM DIVERTING A VEHICULAR TRIP TO THE CBD INTO A CH
C     ANGE OF MODE TRIP. THE UNIT OF SAVINGS IS DOLLARS PER PAR
C     K AND RIDE VEHICLE.
C
C     THIS PROGRAM GENERATES SAVINGS DATA AND IN A FACTORIAL FO
C     RM. THE FACTORS NEEDED, THEIR LEVELS AND UNITS ARE:
C     1- AERIAL DISTANCE OF TRANSIT STATION TO CBD (7 LEVELS, M
C        ILES).
C     2- POPULATION OF METROPOLITAN AREA (6 LEVELS, 1000 PERSON
C        S).
C     3- TYPE OF TRANSIT BEEING TRANSFERED TO (2 LEVELS, BUS OR
C        RAIL).
C     4- RATIO : KISS AND RIDE STALLS TO TOTAL STALLS IN CHANGE
C        OF MODE LOT (4 LEVELS, PERCENT).
C     5- DISTANCE OF CHANGE OF MODE LOT TO ITS ARTERIAL ACCESS
C        (3 LEVELS, BLOCKS).
C
C     THE DATA THUS GENERATED IS USED AS INPUT TO THE BMD2R PRO
C     GRAM, IN ORDER TO DETERMINE THE SAVINGS THAT ACCRUE TO A
C     COMMUNITY FROM A MULTIPLE LINEAR REGRESSION EQUATION.
C
C
C
C     THE INPUT DATA NEEDED FOR FACTORIAL DEVELOPMENT IS:
C     1- LEVELS OF METRO AREA POPULATION, POP(I), GRTER THAN 40
C     2- LEVELS OF STATION DIST TO CBD, CBD(J), GREATER THAN  1
C     3- LEVELS OF TYPE OF TRANSIT, TRSTYP(K),              1 OR 2
C     4- LEVELS OF PERCENT KISS AND RIDE, PPKSR(L),GRTER THN  1
C     5- LEVELS OF LOT DIST TO ACCESS, DDCOR(M),SMALLER THAN 11
C
C     THE INPUT DATA NEEDED FOR SIMULATION IS:
C     1- UNIT COSTS OF VEHICULAR TRIPS (DOLLARS/VEH-MILE)
C                 TIME     OPERATION ACCIDENT  POLLUTION
C        CBD     0.187      0.142      0.007      0.023
C        LOCL    0.100      0.128      0.007      0.015
C        ARTL    0.081      0.123      0.005      0.012
C        EXPS    0.046      0.113      0.002      0.006
C     2- TERMINAL TIME OF AUTO COMMUTER TRIP TO CBD (7 MINUTES,
C        ONE WAY TRIP)
C     3- UNIT COST OF TIME BY TRANSIT(DOLLAR/PASSENGER-MILE)
C                 RAIL         BUS
C                0.042        0.059
C     4- TERMINAL TIME FOR CHANGE OF MODE PASSENGERS (MINUTES,
C        ONE WAY TRIP).
C                 RAIL         BUS
C        PK-RD    7.5         11.0
C        KS-RD    6.5         10.0
C
C     THE INPUT DATA NEEDED FOR PARAMETRS USED IN SIMULATION IS:
```

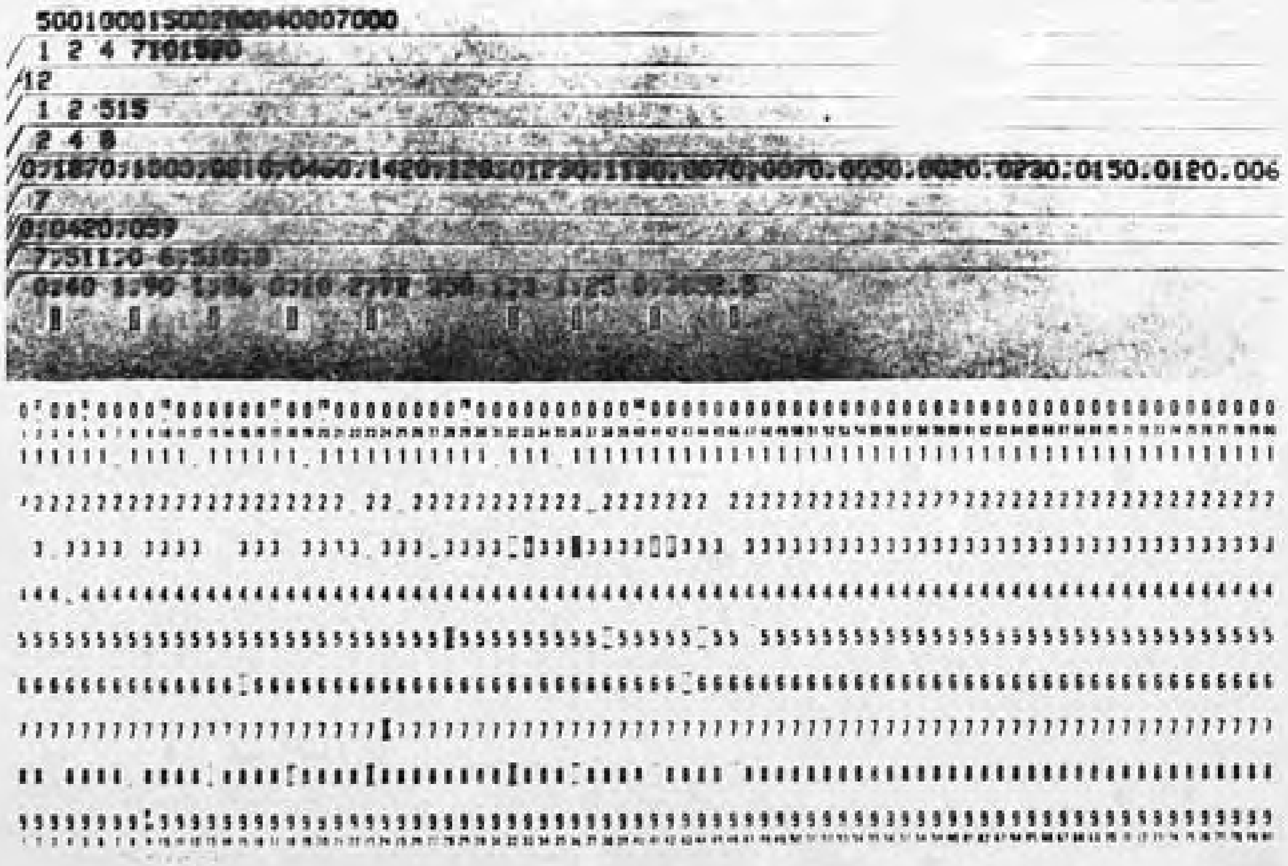
```
1- (A) A VEHICULAR TRIP WITH LENGTH A OR LESS IS MADE ON
   LOCAL STREETS ONLY (0.40 MILES)
2- (B) A VEHICULAR TRIP WITH LENGTH B OR LESS BUT GT THAN
   -A- IS MADE ON LOCAL AND ARTERIAL STREETS ONLY (1.90
   MILES).
3- (C) CHANGE OF CAR OCCUPANCY (1.36 PERSONS/CHANGE
   OF MODE VEHICLE)
4- (D) RATIO OF YEARLY PRODUCTUVITY TO LAND COST (0.10)
5- (E) BASE OF NATURAL LOGARITHM (2.72)
6- (F) CHANGE OF MODE VEHICLE STALL SIZE (350 FEET 80)
7- (G) PARKING TURNOVER RATE AT CHANGE OF MODE LOT (1.3
   PARK AND RIDE VEHICLES/STALL-DAY)
8- (H) COST OF COMMUTER TRAVEL TIME (1.25 DOLLARS/PERSON-
   HOUR)
9- (HH) LAND PRODUCTIVITY IN CBD (0.365 DOLLARS/PRKD VEH)
10- (HHH) MAXIMUM CAR OCCUPANCY (2.5 CHANGE OF MODE
   TRANSIT PASSENGERS/PARK AND RIDE VEHICLE).

====================================================================
====================================================================

DIMENSION AND IDENTIFICATION OF ARRAYS AND VARIABLES
DIMENSION TIME(2,2),POP(6),CBD(7),TRSTYP(2),PPKSR(4)
DIMENSION PERC(4,4),DDCOR(3),TTCT(2)
REAL MAPOP
INTEGER DDCOR


FORMAT AND READING OF INPUT DATA FOR FACTORIAL DEVELOPMNT
FORMAT(6F4.0)
FORMAT(7F2.0)
FORMAT(2F1.0)
FORMAT(4F2.0)
FORMAT(3I2)
READ(5,150)(POP(I),I=1,6)
READ(5,151)(CBD(J),J=1,7)
READ(5,152)(TRSTYP(K),K=1,2)
READ(5,153)(PPKSR(L),L=1,4)
READ(5,154)(DDCOR(M),M=1,3)

FORMAT AND READING OF INPUT DATA FOR SIMULATION
FORMAT(16F5.3)
FORMAT(F2.0)
FORMAT(2F5.3)
FORMAT(4F4.1)
READ(5,157)((PERC (I,J),J=1,4),I=1,4)
READ (5,158) ATMTIM
READ(5,159)(TTCT(K),K=1,2)
READ(5,160)((TIME(L,M),M=1,2),L=1,2)

FORMAT AND READING OF INPUT DATA OF PARAMETERS
FORMAT(8F5.2,F4.0,F4.1,F5.2,F6.3,F3.1)
READ(5,163) A,B,C,D,E,F,G,H,HH,HHH

FORMAT FOR OUTPUT AND PRINTING OF HEADING.
FORMAT(40H      MAPOP     SDCBD     TRANS      PKSR,6X,
154HDCOR     COMCST    PRDCBD    AUTCST    PRDSTA     TERRFT)
FORMAT(6F10.0,5F14.2)
```

```
168   FORMAT(F5.2,5F6.0)
      WRITE(6,166)
C
C
C     START OF SIMULATION PROCEDURE AND RENAMING OF SIMULATION
C     FACTORS.
C
      DO 1000 M=1,3
      DO 1000 L=1,4
      DO 1000 K=1,2
      DO 1000 J=1,7
      DO 1000 I=1,6
      SDCBD=CBD(J)
      MAPOP=POP(I)
      TRANS=TRSTYP(K)
      PKSR=PPKSR(L)
      DCOR=DDCOR(M)
C
C     EQUIVALENT CAR OCCUPANCY OF PARK AND RIDE VEHICLES,IN
C     CHANGE OF MODE TRANSIT PASSENGERS PER PRK-RIDE VEHICLE.
      TSTPGR=0.930-PKSR**0.25*0.978+SDCBD*0.0427*(1000/MAPOP)
     1**2.*0.79*PKSR**0.2*0.545+SDCBD**0.5*PKSR**0.25*0.0779
      IF(TSTPGR.GE.C) GO TO 9
      TSTPGR=C
      GO TO 10
9     IF(TSTPGR.LT.HHH) GO TO 10
      TSTPGR=HHH
C
C     ================================================================
C     ================================================================
C
C     COMPUTATION OF CHANGE OF MODE TRIP COST TO COMMUNITY
C     1- CALCULATE AVERAGE DRIVING DISTANCE TO PARK AND RIDE LOT
C     2- CALCULATE DISTANCES OF TRIP TO LOT OVER DIFFERENT TYPES
C        OF STREETS.
C     3- CALCULATE COST TO COMMUNITY OF AUTO PORTION OF CHANGE
C        OF MODE TRIP
C     4- CALCULATE COST TO COMMUNITY OF TRANSIT PORTION OF CHAN
C        GE OF MODE TRIP
C
C     1- AERIAL DRIVING DISTANCE TO PARK AND RIDE LOT FOR TRANSFER
C     TO RAIL
10    IF(TRANS.NE.1.) GO TO 12
      IF(SDCBD.GE.(3.185*ALOG10(MAPOP/19.))) GO TO 11
      ADDSTA=1.286*SDCBD-1.286
      GO TO 15
11    ADDSTA=(4.1*ALOG10(MAPOP/19.)-1.286)*E**(-0.324*(SDCBD-
     13.185*ALOG10(MAPOP/19.)))
      GO TO 15
C
C     AERIAL DRIVING DISTANCE TO PARK AND RIDE LOT FOR TRANSFER
C     TO BUS
12    IF(SDCBD.GE.(3.899*ALOG10(MAPOP/19.))) GO TO 13
      ADDSTA=0.609*SDCBD-0.609
      GO TO 15
13    ADDSTA=(2.153*ALOG10(MAPOP/19.)-0.609)*E**(-0.324*(SDCBD
     1-3.899*ALOG10(MAPOP/19.)))
C
```

```
C     AVERAGE OVER THE ROAD DRIVING DISTANCE TO PARK AND RIDE
C     LOT.
15    RODSTA=1.2*ADDSTA+0.8
C
C     2- PROPORTIONS OF TRIP TO LOT OVER ALL TYPES OF STREETS WHEN
C     LENGTH IS EQUAL OR SMALLER THAN (A).
      IF(ADDSTA.GT.A) GO TO 24
      PLOC=1.0
      PART=0
      PEXP=0
      GO TO 26
C
C     PROPORTIONS OF TRIP TO LOT OVER ALL TYPES OF STREETS WHEN
C     LENGTH IS EQUAL OR SMALLER THAN (B) BUT LARGER THAN (A)
24    IF(ADDSTA.LE.A.OR.ADDSTA.GT.B) GO TO 25
      PLOC=A/ADDSTA
      PART=(ADDSTA-A)/ADDSTA
      PEXP=0
      GO TO 26
C
C     PROPORTIONS OF TRIP TO LOT OVER ALL TYPES OF STREETS WHEN
C     LENGTH IS LARGER THAN (B)
25    PLOC=A/ADDSTA
      PART=(B-A)/ADDSTA
      PEXP=(ADDSTA-B)/ADDSTA
C
C     DISTANCES DRIVEN OVER ALL TYPES OF STREETS IN TRIP TO LOT
26    RSTAC=RODSTA*PLOC
      RSTAT=RODSTA*PART
      RSTAP=RODSTA*PEXP
C
C     3- COST OF TRAVEL TIME, OPERATION, ACCIDENTS AND POLLUTION
C     IN AUTO PORTION OF CHANGE OF MODE TRIP.
      TTTCST=PERC(1,2)*RSTAC+PERC(1,3)*RSTAT+PERC(1,4)*RSTAP
      TOPCST=PERC(2,2)*RSTAC+PERC(2,3)*RSTAT+PERC(2,4)*RSTAP
      TACCST=PERC(3,2)*RSTAC+PERC(3,3)*RSTAT+PERC(3,4)*RSTAP
      TPLCST=PERC(4,2)*RSTAC+PERC(4,3)*RSTAT+PERC(4,4)*RSTAP
C
C     COST OF AUTO PORTION OF CHANGE OF MODE TRIP IN DOLLARS PER
C     PARKED VEHICLE.
      TAUCST=(TTTCST*2.)*(1.+(TSTPGR-C)/C)+(TOPCST+TACCST+TPLCST)
     1*(1.+2.*((TSTPGR-C)/C))*2.
C
C     4- COST OF TRAVEL TIME,FARE AND TERMINAL TIME IN TRANSIT POR
C     TION OF CHANGE OF MODE TRIP.
      TSTCST=TTCT(K)*SDCRD
      TSFCST=(0.2*(SDCRD**(-0.646)))*SDCRD
      TTMCST=(H/60.*((TSTPGR-C)*TIME(2,K)+C*TIME(1,K)))
C
C     COST OF TRANSIT PORTION OF CHANGE OF MODE TRIP IN DOLARS
C     PER PARKED VEHICLE.
      TTSCST=(TTMCST+(TSTCST+TSFCST)*TSTPGR)*2.
C
C     COST OF CHANGE OF MODE TRIP IN DOLLARS/PARKED VEHICLE
      COMCST=TAUCST+TTSCST
C
C     *****************************************************************
C     *****************************************************************
```

```
C
C      COMPUTATION OF AUTO CBD TRIP COST TO COMMUNITY:
C      1- CALCULATE AVERAGE DRIVING DISTANCE TO CBD
C      2- CALCULATE DISTANCES OF TRIP TO CBD OVER DIFFERENT TYPES
C         OF STREETS.
C      3- CALCULATE COST TO COMMUNITY OF AUTO TRIP TO CBD
C
C      1- AERIAL DRIVING DISTANCE TO CBD
       ADDCBD=(SDCBD**2.+ADDSTA**2.+1.73*SDCBD*ADDSTA)**.5
C
C      AVERAGE OVER THE ROAD DRIVING DISTANCE TO CBD
       RDDCBD=1.2*ADDCBD+0.8
C
C      2- PROPORTIONS OF TRIP TO CBD OVER ALL TYPES OF STREETS
C      WHEN LENGTH IS EQUAL OR SMALLER THAN (A)
       IF(ADDCBD.GT.A) GO TO 16
       PCBD=.5
       PLOC=.5
       PART=0
       PEXP=0
       GO TO 18
C
C      PROPORTIONS OF TRIP TO CBD OVER ALL TYPES OF STREETS WHEN
C      LENGTH IS EQUAL OR SMALLER THAN(B) BUT LARGER THAN (A)
16     IF(ADDCBD.LE.A.OR.ADDCBD.GT.B) GO TO 17
       PCBD=.5*(A/ADDCBD)
       PLOC=PCBD
       PART=(ADDCBD-A)/ADDCBD
       PEXP=0
       GO TO 18
C
C      PROPORTIONS OF TRIP TO CBD OVER ALL TYPES OF STREETS WHEN
C      LENGTH IS LARGER THAN (B)
17     PCBD=.5*(A/ADDCBD)
       PLOC=PCBD
       PART=(B-A)/ADDCBD
       PEXP=(ADDCBD-B)/ADDCBD
C
C      DISTANCES DRIVEN OVER ALL TYPES OF STREETS IN TRIP TO CBD
18     RCBDD=RDDCBD*PCBD
       RCBDC=RDDCBD*PLOC
       RCBDT=RDDCBD*PART
       RCBDP=RDDCBD*PEXP
C
C      3- COST OF TRAVEL TIME, OPERATION, ACCIDENTS, POLLUTION,
C      CBD PARKING AND TERMINAL TIME FOR AUTO TRIP TO CBD
       ATTCST=PERC(1,1)*RCBDD+PERC(1,2)*RCBDC+PERC(1,3)*RCBDT+
      1PERC(1,4)*RCBDP
       AOPCST=PERC(2,1)*RCBDD+PERC(2,2)*RCBDC+PERC(2,3)*RCBDT+
      1PERC(2,4)*RCBDP
       AACCST=PERC(3,1)*RCBDD+PERC(3,2)*RCBDC+PERC(3,3)*RCBDT+
      1PERC(3,4)*RCBDP
       APLCST=PERC(4,1)*RCBDD+PERC(4,2)*RCBDC+PERC(4,3)*RCBDT+
      1PERC(4,4)*RCBDP
       APKCST=(0.42*ALOG10(MAPOP/34.))
       ATMCST=ATMTIM*H*C/60.0
C
C      COST OF AUTO COMMUTER TRIP TO CBD IN DOLLARS PER PARKED
```

```
C     VEHICLE.
      AUTCST=(ALICST+AOPCST+AACCST+APLCST+AIMCST+APKCST)
     1*2.*(1.+(TSTPGR-C)/C)
C
C     ================================================================
C     ================================================================
C
C     LAND PRODUCTIVITY IN CBD (DOLLARS/PARKED VEHICLE)
      PRDCBD=RR*(1.+(TSTPGR-C)/C)
C
C     LAND PRODUCTIVITY AT PARK AND RIDE LOT SITE (DOLLAR/PKD V)
      IF(SDCBD.GE.(0.59*MAPOP**(0.21))) GO TO 22
      DENSTY=(3.95*MAPOP**(0.205)*ALOG10(17.4*SDCBD))/(1.0)+
     10.21*ALOG10(MAPOP))
      GO TO 23
22    DENSTY=(4.34*MAPOP**(0.21))*E**(-0.13*(SDCBD-.59*MAPOP
     1**(0.21)))
23    STALV=(4968*DENSTY-1)1.1*DEDIST)**2.)
      CFLV=1.67*JCUR**(-0.435)
      PRDSTA=(STALV*D*F*CFLV)/(533.*44.56*365.*G)
C
C     SAVINGS TO COMMUNITY FROM CHANGE OF MODE
      TERMFT=((AUTCST-PRDSTA)-(COMCST-PRDCBD))*0.20
C
C     ================================================================
C     ================================================================
C
      WRITE(6,167) MAPOP,SDCBD,TRANS,RASH,UCAR,
     1COMCST,PRDCBD,AUTCST,PRDSTA,TERMFT
1000  CONTINUE
      STOP
      END
```



APPENDIX F

DESIGN CRITERIA COMPUTERIZED PACKAGE, WITH ALTERNATE OUTPUT

```
      PROGRAM DESIGN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      REAL MAREA, MINPCTY MAXPCTY, LIFE
   57 FORMAT (F6.0,F4.0)
   58 FORMAT (3F5.0)
   59 FORMAT (2F5.0)
   60 FORMAT (3F5.0)
   61 FORMAT (3F5.0)
   62 FORMAT (2I5)
   63 FORMAT (I5,F5.0)
   64 FORMAT (25H      PARKING FEE RATING =,F5.1,2X)
   65 FORMAT (23H      MAINTENANCE RATE =,F5.1,2X/)
   66 FORMAT (22H      ATTENDANTS RATE =,F5.1,2X/)
   67 FORMAT (25H      KISS AND RIDE RATE =,F5.1,2X/)
   68 FORMAT (20H      FACILITY SIZE =,F5.0,2X,6HSTALLS/)
   69 FORMAT (45H ** CRITERIA **** CRITERIA **** CRITERIA ****,
     118H CRITERIA **** CO1///)
   70 FORMAT (24H      CRF ON INVESTMENT =,F6.3//////////)
   71 FORMAT (25H      COMMUNITY BENEFITS =,F8.0,2X,9HDOLLARS /,
     14HYEAR/)
   72 FORMAT (23H      COMMUNITY SAVING =,F5.2,2X,11HDOLLAR /VEH
     1,8HICLE-DAY/)
   73 FORMAT (20H      RUNNING COSTS =,F7.1,2X,14HDOLLAR /STALL-
     1,4HYEAR/)
   74 FORMAT (25H      CAPITAL INVESTMENT =,F6.2,2X,9HDOLLARS /,
     111HSQUARE FOOT/)
   75 FORMAT (48H ** FEASIBILITY **** FEASIBILITY **** FEASIBIL
     1,17HITY **** FEASIBIL///)
   76 FORMAT (24H      PERCENT OCCUPANCY =,F6.1,2X,7HPERCENT////
     1///////)
   77 FORMAT (25H      TRANSIT PASSENGERS =,F7.0,2X, 9HPASSENGER
     1,6HS /DAY/)
   78 FORMAT (20H      KISS AND RIDE =,F6.0,2X,12HVEHICLE /DAY/)
   79 FORMAT (20H      PARK AND RIDE =,F6.0,2X,12HVEHICLE /DAY/)
   80 FORMAT (1H1,42H ** DEMAND **** DEMAND **** DEMAND **** DE
     1,21HMAND **** DEMAND ****///)
   81 FORMAT (1H1,40HTHERE IS NO ECONOMICALLY FEASIBLE DESIGN//
     1/////////////////////////////)
   82 FORMAT (41H THERE IS NO ECONOMICALLY FEASIBLE DESIGN/////
     1////////////////////////)
      READ (5,63) IZMAX,STALL
      READ (5,62) MINFLX,MAXFLX
      READ (5,61) LIFE,ROR,CCONST
      READ (5,60) RELMIN,RELMAX,DAYS
      READ (5,59) FACDIS,AMTDIS
      READ (5,58) TRNST,RONR,TYPE
      READ (5,57) POPULN,MAREA
      SMPITI = -0.001
      FLXMIN = MINFLX
      MINFLX = MINFLX + 1
      MAXFLX = MAXFLX + 1
      MINREL = RELMIN
      MAXREL = RELMAX
      CRFCTR = ROR * (1.+ROR) ** LIFE / ((1.+ROR) **LIFE - 1.)
      A0 = 130.
      A1 = 5.8
      A2 =-570.
```

```
      A3 = 215.
      A4 =-20.
      B0 = 0.02627
      B1 = 0.00002
      B2 = 0.04498
      B3 =-0.15028
      B4 =-0.00261
      B5 = 0.00193
      B6 =-0.00001
      B7 = 0.14300
      B8 =-0.01333
      D0 =-0.70479
      D1 = 0.00940
      D2 = 1.96438
      D3 = 1.21122
      D4 = 0.00088
      D5 = 0.00867
      D6 = 0.04868
      D7 =-0.01929
      E = 2.718
      MINPCY = 1.36
      MAXPCY = 2.5
      IF (FACDIS.GE.(0.59*POPULN**(0.21))) GO TO 22
      DENSTY = (3.59*POPULN**(0.205)*ALOG10(17.4*FACDIS))/(1.01
     1+0.21*ALOG10(POPULN))
      GO TO 23
   22 DENSTY = (4.54*POPULN**(0.21))*E**(-0.13*(FACDIS-0.59*POP
     1ULN**(0.21)))
   23 STALV = (4968*DENSTY-111.1*DENSTY**2.)/(533.*43.58)
      CLOVLU = STALV*1.67*ARTDIS**(-0.435)
      CINVST = CLOVLU*CCONST
      DO 100 I= 25,IZMAX,25
      SIZE = I
      DO 100 J = MINFLX,MAXFLX
      FLXBTY = J-1
      PCKISS = FLXBTY - FLXMIN
      DO 100 K = MINREL,MAXREL
      RELATY = K
      DO 100 L = 1,6
      PRKFEE = L
      DMNDOS = D0 + D1*SIZE + D2*RORB + D3*RELATY + D4* TRNST**
     12. + D5*MAREA**2. + D6*FLXBTY*PRKFEE + D7*TRNST*RELATY
      DEMAND = DMNDOS**2.
      PCCY = (DEMAND/SIZE)*100.
      IF (PCCY.GT.95.0) GO TO 100
      CRUNIG = A0 + A1*RELATY + A2*DEMAND/SIZE + A3*DEMAND*PRKF
     1EE/SIZE + A4*DEMAND*PRKFEE**2./SIZE
      IF (CRUNIG.LT.0.) GO TO 100
      SAVING = B0 + B1*POPULN + B2*FACDIS + B3*TYPE + B4*PCKISS
     1+ B5*FACDIS**2. + B6*POPULN*FACDIS + B7*PRKFEE + B8*PRKFE
     2E**2.
      IF ((DAYS*SAVING*DEMAND).LT.(STALL*CINVST*SIZE*CRFCTR + C
     1RUNIG*SIZE)) GO TO 100
      BENFIT = (DAYS*SAVING*DEMAND) - (STALL*CINVST*SIZE*CRFCTR
     1+ CRUNIG*SIZE)
      IF (BENFIT.LE.BNFIT1) GO TO 100
      BNFIT1 = BENFIT
      P = PRKFEE
```

```
      F = FLXRTY
      R = RELRTY
      Z = SIZE
      D = DEMAND
  100 CONTINUE
      IF (BNFIT1.GE.0.) GO TO 45
      WRITE (6,81)
      WRITE (6,82)
      WRITE (6,82)
      STOP
   45 PCKISS = F - FLXMIN
      TSTPGR = 0.43 -PCKISS**0.25*0.978 + FACDIS*0.0427 + (1000
     1./POPULN)**2.*0.79 +PCKISS**0.50*0.545 + FACDIS**0.5*PCKI
     2SS**0.25*0.0779
      IF (TSTPGR.GE.MINPCY) GO TO 50
      TSTPGR = MINPCY
      GO TO 51
   50 IF (TSTPGR.LT.MAXPCY) GO TO 51
      TSTPGR = MAXPCY
   51 PCTOCY = (D/Z)*100.
      PSNGER = TSTPGR*D
      VHKISS = (PSNGER - MINPCY*D) / MINPCY
      SAVING = B0 + B1*POPULN + B2*FACDIS + B3*TYPE + B4*PCKISS
     1+ B5*FACDIS**2. + B6*POPULN*FACDIS + B7*P + B8*P**2.
      CRUNIG = A0 + A1*R + A2*D/Z + A3*D*P/Z + A4*D*P**2./Z
      CRF = (DAYS*SAVING*D - CRUNIG*Z) / (STALL*CINVST*Z)
      RTMNTC = 0.67*(R-FLOAT(MINREL))
      RTATND = 0.33*(R-FLOAT(MINREL))
      WRITE (6,80)
      WRITE (6,79) D
      WRITE (6,78) VHKISS
      WRITE (6,77) PSNGER
      WRITE (6,76) PCTOCY
      WRITE (6,75)
      WRITE (6,74) CINVST
      WRITE (6,73) CRUNIG
      WRITE (6,72) SAVING
      WRITE (6,71) BNFIT1
      WRITE (6,70) CRF
      WRITE (6,69)
      WRITE (6,68) Z
      WRITE (6,67) PCKISS
      WRITE (6,66) RTATND
      WRITE (6,65) RTMNTC
      WRITE (6,64) P
      STOP
      END
```

THERE IS NO ECONOMICALLY FEASIBLE DESIGN

THERE IS NO ECONOMICALLY FEASIBLE DESIGN

THERE IS NO ECONOMICALLY FEASIBLE DESIGN

VITA

VITA

Usamah R. Abdus-Samad was born March 24, 1943 in Beirut, Lebanon. He completed his secondary education at the Lyçée Francais de Beyrouth and received his Diplome de Bachelier de l'Enseignement Secondaire (Serie Mathematiques) in 1961.

He entered the American University of Beirut and received his B.E. (Major: Civil) with distinction in 1965. He was also awarded Engineering Honors.

In 1965 he worked as a Consultant for the Department of Social Development, Ministry of Labor and Social Affairs, Lebanese Republic.

He was appointed a research assistant at the Thayer School of Engineering, Dartmouth College in 1966, and received his M.E. in 1968. Since then he has been a research assistant and graduate instructor at Purdue University.

He is a member of the Lebanese Order of Engineers, the Dartmouth Society of Engineers, the Highway Research Board, an associate member of the American Society of Civil Engineers, a junior member of the Institute of Traffic Engineers. He is a fellow of the Conseil National (Lebanon) de Recherche Scientifique.