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MODEL FOR FORECASTING USAGE OF PUBLIC TRANSPORTATION IN IOWA CITIES

by

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TABLE OF CONTENTS

INTRODUCTION

Within the past few years, urban transportation planning activities have been undertaken in all except the smallest cities in the United States. This is due to a growing recognition that development of transportation facilities in urban areas no longer can be permitted to proceed as a haphazard or random process. Congestion on streets is increasing to the extent that it is troublesome in most cities. Increasing congestion usually is accompanied by a considerable dispersion of residential, commercial, and industrial activities and a corresponding decline in the vitality of central business districts. This has resulted in an erosion of the tax base, an increase in the costs of providing necessary public services, and a failure to check the spread of blight into ever larger portions of a city.

The cause and effect relationships between congestion and urban blight are not always apparent. It has been said that congestion leads to blight. It also has been stated that urban blight leads to congestion. However, it is clear that the two occur together. Their occurrence has helped to supply the incentive for cities to undertake the comprehensive planning without which there can be no satisfactory solution to the problems of transportation.

Urban transportation studies are concerned with a systematic approach to the solution of existing and anticipated problems involved in the movement of goods and people in urban areas. These problems are considered in relationship to planning for land use and other physical planning. Data are collected concerning the economic and social characteristics of the inhabitants and the physical characteristics of the urban area. Travel habits are defined further by origin-destination surveys. Past trends are studied and forecasts are made of the quantity of travel in the future and its distribution.

The major portion of a plan formulated as a result of the analysis of data developed is concerned with the movement of people in an urban area. Most personal travel in smaller urban areas is carried out by means of privately owned automobiles. Consequently, the physical planning growing out of transportation studies is concerned largely with improvements or additions to the street system. The need for such improvements is made apparent by comparisons between the amounts of vehicular traffic to be carried and the capacities of segments of a street system to carry this traffic. Deficiencies in capacity result in congestion and it is congestion with its many undesirable effects which the transportation studies are intended to alleviate.

Congestion may be defined as a condition resulting when there are more vehicles using the principal components of a street system than these components are capable of carrying without unreasonable hazard and delay. Depending upon the city, its street system may have been developed centuries earlier or decades earlier for a vastly lesser number of vehicles of a type differing substantially from the vehicles in use today. The streets found in the central areas of most cities were entirely adequate for the few dozen horse-drawn vehicles per hour for which they were intended to provide service. However, the several hundreds of automobiles and trucks using these same streets hourly during most periods of the day have caused today's problem. The magnitude of this problem is increased during early morning and late afternoon traffic peaks when most travel between home and work is concentrated.

Another factor has contributed significantly to the increase in traffic congestion. This is the fact that urbanized areas have become larger so that streets must provide for the interchange of trips being made by more people. To aggravate further the problem of more people using a newer form of travel which requires more roadway space, these people are traveling more today than at any previous time. The automobile has increased the propensity for people to make trips. As a consequence, we now find more people in urbanized areas making more trips per person than ever before.

Most urban trips in Iowa are made by private automobile. Although there is considerable variation from city to city, the proportion of personal travel by private automobile is well over 90 percent in all cities in the state. Many of these automobiles are carrying only one person, the driver. According to origin-destination surveys made recently in Iowa, the typical automobile trip made in urban areas carries only about 1.6 persons. Furthermore, the use of public mass transportation has declined steadily since 1945. Hence, not only are more urban trips being made than at any previous time, but the number of vehicles is increasing even more rapidly than the number of trips since so many more now are being made in automobiles carrying only one or two persons. The problem of vehicle congestion on urban streets is compounding itself at an increasing rate.

A look at some statistics is revealing as it concerns the changes which have occurred in urban travel habits. During World War II, patronage of public transportation was at an all time high in the United States. Almost 19 billion revenue passengers were carried during 1945 (2). Also in 1945, there were 130 billion vehicle-miles of travel by motor vehicles on urban streets (3). After the removal of wartime restrictions on motor vehicle travel, transit patronage declined rapidly. In 1950, fewer than 14 billion revenue passengers were carried on transit lines of the United States while urban motor vehicle travel increased to 218 billion vehicle-miles. Despite the fact that urban area populations have increased markedly since 1950, transit ridership has continued to decline. The trend toward suburbanization, continued economic prosperity, and the increase in automobile ownership resulting from these factors have continued to lead to a substantial growth in motor vehicle travel and further decline in transit patronage. During 1963 there were 385 billion vehicle-miles of urban travel by motor vehicle (almost 3 times that in 1945) while transit carried fewer than 7 billion revenue passengers (about 36 percent of the number carried in 1945).

Trends in transit ridership in cities in Iowa exhibit similar characteristics. Only three companies in Iowa have records available for the entire period 1950 through 1964 and these all show substantial declines. Based on the annual number of revenue-producing transit trips per resident of the area served, transit usage in Des Moines dropped from 153 in 1950 to under 27 in 1964. The comparable number of annual trips per capita in Dubuque were 133 in 1950 and 52 in 1964. In Burlington, patronage decreased from 91 trips per person per year in 1950 to under 15 in 1964. Declining use of public transportation accompanied by a rapidly growing use of private automobiles is one of the factors contributing to increased congestion on urban streets.

Whatever the exact cause of congestion and its resultant problems, the seeking of a solution begins with studies which follow the general pattern described previously. Requirements for personal travel are estimated and are then converted to a corresponding number of vehicle trips. Whether the facilities being planned cover all the components of an urban transportation system or are confined to major streets and highways, it is necessary to distinguish between person-trips which utilize private automobiles for travel and those utilizing public transportation. The division of person-trips between the two alternatives, called the modal split, must be estimated with reasonable accuracy if the planned facilities are to be both adequate and economical.

The modal split has usually been defined in terms of a percentage, the percentage being that portion of the total number of person-trips in a given urban area which will utilize public transportation. Quantities generally are expressed on a daily basis for a typical week day. However, the model developed from the research reported here describes the usage of public transportation in terms of the number of annual rides per resident of the service area of a given transit operation. The total number of revenue passengers carried annually is simply the product of this quantity and the total population of the area served. This annual total may be converted readily to daily person-trips if the service characteristics of a particular transit operation are known.

A revenue passenger is any patron making a single trip for which a fare has been paid for travel on a vehicle operating as part of a regularly scheduled intracity transit operation. A single trip may involve transfer between vehicles, however. Special services such as chartered trips or buses operated under contract exclusively to transport children to and from school are not included.

As stated previously, increasing congestion on urban streets and highways has tended to focus attention upon the need for solutions to the problems associated with urban transportation. Comprehensive transportation planning processes have been undertaken in many urban areas in recognition of this need. However, further incentive to carry out such planning has been offered by recent federal legislation dealing with the federal-aid highway program and programs of assistance to mass transportation. These laws require that federal-aid funds for transportation be authorized for expenditure in an urban area only if there exists a cooperative, continuing, comprehensive transportation planning process in that urban area. Furthermore, the improvements for which expenditures are to be authorized must be included in the plan formulated. Although such legislation dealing with highways is applicable only in cities with populations of at least 50,000, transportation planning also is being carried out in increasing numbers of smaller cities.

A feature of the increased attention devoted to transportation has been a renewal of interest in public mass transportation. There is growing concern that the inability of most transit companies to operate profitably while providing service at desirable levels will lead to a discontinuance of operations. In turn, this will increase the problems of congestion by forcing increased numbers of trips to be made by private automobile. It will also remove the freedom of choice between alternative modes of travel which is considered by many authorities to be desirable in a society so well endowed with material possessions.

The problems of transit companies are particularly acute in Iowa. A study covering all of its member companies and conducted by the Iowa Transit Association for the fiscal year ending June 30, 1964, showed a net operating loss of $272,839 on gross operating revenues of $5,159,495 (10). This combined financial picture has presented a steady decline in net earnings year by year. However, there is a considerable difference between transit companies in Iowa. Some companies are strongly financed and are being operated profitably. On the other hand, several cities in Iowa are faced shortly with abandonment of transit operation unless a different concept of financing such service is adopted.

PURPOSE AND SCOPE

Planning for urban transportation requires knowledge of the extent to which public transit will be utilized for personal travel. It is necessary that the number of person-trips made by this means be established with reasonable accuracy. Such knowledge is essential whether a planning effort is concerned only with streets and highways, exclusively with public mass transportation, or if it is considering an urban system involving travel by all modes of transportation.

A method of describing transit patronage in terms of a modal split has some important disadvantages, particularly for a study concerned only with public mass transportation. It first involves a determination of the total quantity of urban travel by all modes. This determination is very expensive and time consuming by the method most commonly utilized wherein trip distribution by origin and destination is established first. The total number of person-trips thus determined is then multiplied by the modal split expressed as a percentage. The modal split is calculated using various economic and demographic parameters and the characteristics of a specific transit operation.

In this study, on the other hand, the same parameters are utilized to establish directly the number of transit trips which are likely to occur in an urban area. Calculation of this quantity directly precludes the possibility for increased error inherent in the more usual method whereby a modal split is multiplied by a total number of person-trips to arrive at a figure for transit use. Since both of the terms multiplied together are subject to estimating errors, their product is subject to a much greater possible error.

The model presented here has been derived from a study of available data covering transit operations in 14 cities in Iowa. Since cities in Iowa exhibit economic and physical characteristics which are fairly uniform, the applicability of the model should be considered as limited to cities possessing those characteristics. It would not be applicable for use in very large metropolitan areas, for example, since these generally have characteristics which differ materially from those of any urban areas in Iowa. Nor would it be applicable for use in other smaller urban places outside of Iowa where economic factors, population densities, automobile ownership rates, and demographic characteristics differ from those of cities in Iowa.

Within these limitations, however, the model which is presented is of use to describe quantitatively the patronage of public mass transportation. The independent variables utilized generally are readily available from public sources and are those commonly utilized in social and economic planning and in other physical planning.

It must be recognized that the utilization of data describing past trends for purposes of forecasting human events in the future involves the risk of inaccuracies introduced by significant changes in social customs and personal habits. However, a reasonable expectation is that current trends concerning transit ridership are not subject either to appreciable acceleration or substantial reversal.

If a model is to be useful as a tool for forecasting, it also is important that the independent variables be capable of being projected with reasonable assurance of accuracy. This is believed to be the case with those which have been utilized in the model presented in this paper. Hence, this model should be useful for forecasting transit patronage in the future. It may be utilized in the forecasting phase of urban transportation planning for cities in Iowa or for those in other states which have similar characteristics.

A further objective in the development of a model has been to utilize as few variables as possible while still retaining a desired level of confidence in the results obtained by its use. An attempt also has been made to use those factors for which data is readily available without the necessity for expensive and time-consuming household interviews.

REVIEW OF LITERATURE

Many previous studies have been directed toward the description of transit patronage in terms of some number of independent variables. A number of such studies are discussed in this section. Following this is a discussion of the variables most commonly utilized in these studies as indicators for transit usage.

Reports of Previous Studies

Report by Adams

A study conducted by the Bureau of Public Roads, United States Department of Commerce, has been reported by Adams (1). This study had as its objective "to develop a relationship between the use of public and private transportation in urban areas and the principal factors influencing that use".

The data used were developed from home-interview origin-and-destination surveys conducted in 1948, 1949, 1950, and 1953 in 16 cities. Urban areas were distributed geographically throughout the United States and varied in population from under 100,000 to over one million. Information on transit service was obtained from the transit companies and information on land-use was obtained from the planning agencies of each city. Regression relationships between the modal split and the other variables produced a semilog equation in the following general form:

$$y = A + b_1 \log P + b_2 \log E + b_3 \log T + b_4 \log U + b_5 \log M$$

where y = estimated percentage of total person-trips made via transit

P = population over 5 years of age in the survey urbanized area

E = economic factor

T = transit-service ratio factor

U = land-use distribution factor

M = urbanized land area in square miles

A, b_1, b_2, b_3, b_4, and b_5 are coefficients to be determined by regression analysis

For measurement of M, only land was considered which was contiguously developed. Areas included had a minimum residential density of 55 persons per square mile or a minimum of 2,000 daily trip ends per square mile.

Many other factors were used in the calculation of the three compound factors, E, T, and U, in the above equation. For example, the economic factor E considered the number of employees going to work on an average week day in relation to the number of households and in relation to the total population over 5 years of age. Also included in the determination of the economic factor was the relationship between the number of automobiles owned and the population and number of households.

Three factors were used to determine the transit-service ratio factor, T. The first of these was the number of revenue vehicle-miles of transit service operated per week day (expressed in terms of 50-seat bus revenue miles) related to both population and urbanized land area. The second factor used in determining T related the speeds of automobiles and transit vehicles. A third factor related parking demand and supply.

The land-use distribution factor, U, was compounded from several terms which describe the extent to which population and commercial and industrial activity were dispersed within the urbanized area. Both T and U were less than one so that their logarithms were negative. The constant

b_5 also was negative. Hence, the equation developed from this study produced the following general relationships between the use of transit and the independent variables used:

1. Transit patronage as a percent of total trips tends to be greatest in urban areas having larger populations.

2. A smaller proportion of the population in the work force leads to increased transit patronage.

3. Higher ratios of population to automobiles owned and households to automobiles owned are associated with increased use of transit.

4. Transit patronage is decreased if less service was provided, if auto travel is significantly more rapid than transit travel, or if ample automobile parking is provided near trip termini, although the effect of the last two factors is quite small.

5. Greater dispersion of residential, commercial, and industrial activities within an urbanized area tends to decrease transit patronage.

6. Dispersion of development in an urbanized region is associated with decreased usage of transit.

Comparison of the results yielded by this equation with actual transit use factors in the 16 cities used in its derivation indicated a standard error of estimate for y of less than 1.5 percentage points. Since the estimating equation was developed, it was further tested for 5 additional cities. The results were within this standard error of estimate.

Report by Schwartz

Schwartz in this report presents a discussion of procedures used by the Pittsburgh Area Transportation Study for forecasting transit use (19). Variables which affect the choice of transportation mode were separated into two categories. Major variables exerted the greatest effect and supplemental variables less strongly affected transit use.

Major variables were automobile ownership and net residential density. Of these, automobile ownership was described as the "most important single variable in the determination of the demand for transit". It was pointed out that these two variables are not independent since rates of automobile ownership bear a close relationship to population density.

Among the supplemental variables were various modifiers of net residential density. These gave recognition to the fact that other land uses also serve as trip ends for transit trips. The relationship of population to total land area, or gross residential density, was suggested as an alternative to net residential density as an indicator of the probable demand for transit services. Other minor variables suggested as having some significance in the choice of travel modes were transit vehicle speeds and costs of transit service.

Transit trips were divided into three categories - trips to the central business district (CBD trips), school trips, and all others. Transit use was forecast separately for each category of trip. Forecasts of CBD trips were based on tabulated factors derived for the modal split and dependent upon distance from the CBD, net residential density, and the number of autos per household. School transit trips were calculated in terms of population and residential density. Other transit trips were estimated from a family of curves derived for various net residential densities and for different numbers of cars per household. This method was applied to the specific urban area for which it was derived so it is difficult to evaluate its applicability for other locations. It was used for some small areas to test the effects of certain transit improvements. These tests indicated that increases in the speed of transit vehicles serving the study areas led to an actual number of CBD trips substantially in excess of the expected number.

Some further discussion of the methodology used in the Pittsburgh Area Transportation Study to forecast the use of public transit is included in a report by Keefer (12).

Report by Mortimor

Mortimor reports on the results of a study made by home interviews in Cook County, Illinois (16). Data obtained were used to determine assignment curves for transit use by regression analysis. In all cases, correlation coefficients of greater than 0.90 were obtained.

One of the assignment curves used a time ratio of transit time to time for travel by auto as the independent variable. This curve was in the form

$$y = 41.1x^{-1.85}$$

where y = percent of total trips made by transit

x = time ratio, time by transit ÷ time by auto

From this equation it may be seen that 41.1 percent of all trips in the Chicago area are made by transit if the time ratio is 1.0. Where transit times are only about one-half those by auto, practically all trips are made by transit. Where transit takes twice as long, only about 11 percent utilize transit.

Another curve derived relates transit usage to the relative costs of travel by transit and auto. This curve was expressed

$$y = 7.40x^{-0.886}$$

where y = percent of total trips made by transit

x = cost ratio, cost by transit ÷ cost by auto

Costs for automobile travel included parking. Equal costs may be seen to cause only 7.4 percent of travel to be made by transit. A substantial proportion of total travel is made by transit only if the cost by auto is several times that by transit.

Some of the other conclusions reached from this study are as follows:

1. The absolute time required to make a trip also had a significant influence on the choice of travel mode. Longer trips (in terms of time) within the Chicago area tended to be made by transit.

2. Household income was inversely related to transit usage. The effect of this factor was most pronounced at income levels of less than $5,000 per year.

3. Comfort influenced a decision to choose travel by private automobile in preference to travel by transit. Specific considerations were the necessity to transfer from one vehicle to another or the inability to secure a seat.

<u>Report by Sosslau, Heanue, and Balek</u>

The report by Sosslau, Heanue, and Balek presents a procedure for determination of the modal split developed for the National Capital

Transportation Agency (20). Relative usage of private automobiles and public mass transportation in Washington, D. C., is related to five variables.

1. Time ratio of transit travel to private automobile travel considering door-to-door travel times for both modes.

2. A service ratio which is the ratio of excess time by transit to the excess time by private automobile. Excess time is all time required for door-to-door travel except the time spent on the vehicle. All walking time is included as is the time waiting for a transit vehicle, time transferring between transit vehicles and the time required for parking an automobile.

3. Ratio of out-of-pocket travel costs for public transit to out-of-pocket travel costs for travel by private automobile.

4. The economic status of the person making the trip using median income per worker as a measure of this variable.

5. Trip purpose, which is either home-based work trips, nonwork trips, or trips to school.

The procedure was tested against 1955 origin-destination data and used to forecast transit trips in 1980. It underestimated the total number of trips made by transit in 1955 by only 4.6 percent.

Several tests were devised to demonstrate the sensitivity of this modal split procedure to changes in the parameters. These tests demonstrated that the model was extremely sensitive to changes in the service ratio. For example, when 2 minutes was added to the auto parking and walking times, estimated transit usage increased by 32.7 percent. Other tests indicated also that improvements in the quality of transit service as measured by the ratio of travel times tended to increase markedly the proportion of total travel which utilized public transportation. This tendency was most pronounced among the higher economic status groups. However, transit patronage estimated by this procedure was relatively independent of the fare structure. One test which involved an assumed increase of $0.15 in base fares indicated a decrease in patronage of 5.0 percent. This was accompanied by a 36.7 percent increase in total transit revenues.

Some further information on the development of the model used in this study is contained in a report by Deen, Mertz, and Irwin (6).

Report by Wilbur Smith and Associates

In their report prepared for the Automobile Manufacturers Association, the consulting firm of Wilbur Smith and Associates has summarized factors influencing transit use in 11 cities (23). Transportation studies were conducted in these cities during the period 1953 through 1959. The variables of population density in the urbanized area and automobile ownership were used to establish the percent of trips in the study area which would be made by transit.

These relationships have been used to derive two separate curves described as transit use curves. One of these was for the total of all person-trips within the urban area and the other for person-trips with origin or destination in the central business district. Since mass transportation generally is oriented strongly toward travel to and from the central business district, the proportion of CBD trips made by transit usually was at least double transit's share of all travel made within an urban area.

In these travel mode curves, the independent variable was a transit use factor, defined as follows:

$$\text{Transit Use Factor} = \frac{C \times P}{1000}$$

where C = number of households per car

P = urbanized area population density, persons per square mile

Within the practical range of transit use factors, the curve for total area person-trips is approximately

$$y = 0.85x^{1.5}$$

where y = percent of total trips by transit

x = transit use factor

A transit use factor of 10 is described as typical of large transit-oriented cities. This corresponds to proportions of travel by transit of 27 percent for all person-trips in an urban area and 77 percent for central-business-district person-trips. For medium-sized cities, 5 is a typical transit use factor. With this factor 9 percent of total trips and 22 percent of central-business-district trips are made by transit.

Data from the studies reported in this reference are further developed in a report by Levinson and Wynn (13). In their report, the transit use factor is called an urban travel factor. It is used in one set of curves to represent the proportion of peak-hour person-trips which may be expected to utilize transit. These proportions are significantly higher than those for total daily travel which points out the pronounced concentration of transit travel during rush hours.

Report by Schnore

Schnore in his report examines the data on transportation to work obtained with the 1960 United States Census of Population (18). He relates the use of public transportation to three variables, city size, population density, and the age of the city.

As may be expected from the results of other research, the use of public transportation tends to be greatest in larger cities and varies directly with the density of population. Of the three variables, however, the age of a city correlated most consistently with transit usage. For this analysis, the age was measured by the number of census periods since the population of the central city of an urban area first exceeded 50,000.

Report by Hadden

Hadden has drawn upon the work of Schnore reported above in an investigation of factors relating to the use of public transportation (7). His study, however, was confined to census tracts in Milwaukee so that city size was not pertinent. Data from the 1960 Censuses of Population and Housing were used. Hadden also found a strong correlation of transit usage with both population density and the age of a sector of the city. Two definitions of age were used. In one case, the percentage of housing structures built before 1939 was used as a measure of age. In the other definition, distance from the center of the city was used. The latter definition assumes a centrifugal development of a city in concentric rings with older developments being located adjacent to the city center and with successively newer developments being located at greater distances. Although the actual development of an urban area rarely follows exactly this idealized pattern, a high degree of correlation was found between the use of public transportation and the age of a city sector as thus defined. Correlation with age as defined by older housing structures was less good.

As a sociologist, Hadden was also interested in the relationship between the use of public transportation and various other indicators of socio-economic status. Several of these have not been employed previously in this connection. The variables which Hadden investigated are listed in Table 1. Also indicated are the correlation coefficients for each independent variable.

Table 1. Variables used by Hadden as indicators of the use of public transportation

Variable	Correlation
Percent of units with two or more automobiles	-0.74
Percent of units with no automobiles	0.71
Percent of units owner occupied	-0.66
Median school years completed	-0.65
Percent of divorced females	0.63
Median gross rent	-0.62
Percent of civilian labor force unemployed	0.60
Median value of each dwelling unit	-0.58
Median income of families	-0.55
Percent married women in labor force, husband present	-0.55
Percent of housing units deteriorated and dilapidated	0.52
Percent of males in high status occupations	-0.47
Percent of separated males	0.46
Number of Negroes	0.38
Percent of total labor force female	0.33

From this tabulation, it is evident that high socio-economic status is associated negatively with transit ridership. All of the indicators of high status have negative coefficients of correlation. The best correlations are obtained with those variables which consider automobile ownership.

Report by Kain

In this report, Kain presents a nine-equation econometric model of which one equation deals with the choice of public transit for travel to work (11). The study area consists of 254 employment zones in Detroit, Michigan. Data were gathered from a household survey made by the Detroit Area Traffic Study. The equations which were derived were tested and found to represent adequately the behavioral relationships for white workers. However, for non-whites a more elaborate model is said to be required due to the effects of racial discrimination.

For describing transit use, the following equation is presented (with notation simplified by the writer):

$$M = 86.06 - 22.10A - 0.088R + 3.25L - 0.209S - 0.174Y - 0.358N$$

where M = percentage of workers employed in the zone who ride public transit to work

A = mean automobile ownership of workers employed in the zone

R = percentage of workers employed in the zone who reside in single-family residences

L = level of transit service; daily coach-miles of transit service in the zone divided by the area of the zone in acres

S = percentage of workers employed in the zone who are male

Y = mean family income of workers employed in the zone in hundreds of dollars

N = percentage of workers in the zone belonging to families having a single wage-earner ,

This equation produced a coefficient of correlation of 0.91 with the data obtained from the survey. Tests of elasticity indicated that changes in S, N, and Y produced substantial changes in transit use. Changes of one percent in these variables caused changes respectively of 0.99, 0.88, and 0.76 percent in M. These are the variables which deal with the composition of the labor force and with family income. However, an increase of one percent in the service level induces an increase of only 0.31 percent in the percentage of workers using transit. This fact leads to a conclusion that the level of service is a relatively unimportant factor and that declines in transit patronage are best explained by changes in demographic and economic characteristics of the population. Automobile ownership was an endogenous variable in one of Kain's other equations to be explained in terms of the several exogenous variables. As such it did not appear in the reduced-form equation from which all endogenous variables were eliminated. Since the latter equation was used by Kain for his determination of elasticities, his calculations did not include a determination of elasticity with respect to this variable. However, it may be shown that a change of one percent in automobile ownership causes a change of 1.25 percent in transit usage. Thus, for work trips, automobile ownership is a most significant single variable.

Other reports

In a report prepared for the Eno Foundation for Highway Traffic Control, Schmidt and Campbell developed a relationship between the number of persons per automobile and the selection of a mode of travel (17). They determined that travel was about equally distributed between transit and other modes in areas in which there were 8 persons per auto. For a ratio of 10 persons per automobile, about 69 percent of travel was by transit. Ratios of 2 to 3 persons per vehicle are common in cities in Iowa. For these ratios transit travel was reported as from 4 to 8 percent. These figures were based on 1953 data.

A paper by Booth and Morris discusses a mathematical model which was used in the Baltimore region to estimate existing and future traffic patterns (4). The number of transit trips was estimated using the relationship between the modal split and car ownership per family which was developed by Schmidt and Campbell. For testing alternative plans, assignment to transit travel or auto travel was based on the ratio of travel times of the two alternatives. The assignment curve used was developed from data in Cook County, Illinois, and was essentially that presented by Mortimor and discussed previously.

Research by Hill and Von Cube has established four factors which are reported to be most significant in the determination of the choice of travel mode (9). These are the following:

1. Relative travel time by public transit and private automobile.

2. Relative cost of travel by public transit and private automobile.

3. Relative level of service of the two modes as determined by the excess of travel time for one mode of travel compared to the other.

4. Economic status of trip makers measured by the income per worker.

This study was based on relationships established from travel behavior in Toronto. Surveys made in Washington, D. C., and Philadelphia supplied additional data. It may be noted that the significant factors are the same presented by Sosslau, Heanue, and Balek.

An earlier report by Hill and Dodd covers the Toronto study only (8). Three of the same factors are used with the relative cost of travel not being included.

Discussion of Variables Used to Indicate Transit Usage

From the preceding reports of previous research on the variables affecting transit usage, four factors appear most commonly as indicators. These are automobile ownership, population density, the level of transit service (defined differently by various researchers, however), and one or more indicators of socio-economic status (of which family income is the most common).

It is apparent that these four variables are not independent of each other. Automobile ownership tends to increase as the level of transit service decreases. It also tends to increase with reductions in residential density or with higher socio-economic status. Similarly, higher residential densities most frequently are associated closely with lower socio-economic status. In a multi-model method such as that employed by Kain, those variables which are endogenous may be dropped out and replaced by exogenous variables in a final reduced-form equation. However, in a more usual type of model employing all or several of the variables listed above it should be recognized that a considerable measure of interdependency exists among the so-called independent variables.

The decline in revenue transit passengers from a national total of almost 19 billion in 1945 to under 7 billion in 1963 has been accompanied by a considerable increase in the ownership of passenger automobiles. There were fewer than 26 million passenger cars registered in the United States in 1945. By 1964 this figure was nearly 72 million (3). The trends in transit ridership and automobile ownership unquestionably are related. The flexibility, privacy, comfort, and convenience of travel by private automobile cannot be matched by any conventional forms of mass transportation. Hence, a measure of the extent to which automobile travel is available as an alternative to transit travel is a valid and significant indicator of the extent to which personal travel will be made by public transportation.

Family income is not only a determinant of the likelihood that an automobile will be available for personal travel but also is an indicator of socio-economic status. In the past decade, it has become increasingly evident to transit operators that a person's own evaluation of his status often is negatively associated with his propensity to elect travel by public mass transportation. A measure of social stigma is attached by some people to the practice of riding a public transit vehicle in an era in which travel by private automobile is predominant. For this reason alone the level of income attained by a person is an indicator of the likelihood of his personal travel being made by public transportation.

Areas of high residential density are ideally suited for service by mass transit. More people are served more conveniently in such cases. Fewer miles of travel by transit vehicles in densely populated areas may be expected to produce a greater number of riders and hence to return higher profits than can be expected from service in sparsely populated areas. Average walking distances are reduced when transit lines serve areas with high population densities so that transit service is made more attractive. The fact that low residential densities commonly are associated with high incomes and high rates of automobile ownership serves only to emphasize further the very close relationship between family income, automobile ownership, residential density, and transit usage.

Many researchers have concluded that a substantial portion of regular transit patrons are so-called "captive riders" who have no alternative means of conducting personal travel. These are persons who because of economic status, place of residence, or as a result of an inability to operate motor vehicles must depend upon some form of public transportation for travel. Relatively few persons are in this category in most communities in Iowa. It is apparent, therefore, that increases in transit patronage for the most part must be gained from among persons who have alternative means of transportation available but who choose to avail themselves of public transportation. Such a choice obviously will be influenced by the relative speed, comfort, and convenience of the alternative modes of travel which are available. The cost of one form of transportation relative to that of another may also be of some significance. However, the research reported previously which was done in the Washington, D. C., area indicated that the influence of fares was almost negligible (20). A transit demonstration project carried out on the Boston area also indicated that comparative travel costs are much less important than the factors of speed, comfort, and convenience (14). It undoubtedly is true also that the typical urban resident is unaware of all of the costs associated with travel by private automobile, even those generally categorized as out-of-pocket costs. Hence, he lacks the means for making valid cost comparisons.

There is a notable tendency for public transit to play a more important role in larger cities than it does in smaller cities. Data in the United States Census of 1960 concerning the use of public transportation for travel to work indicate that the greatest proportional use of transit is in New York, Jersey City, Philadelphia, Boston, and Chicago. All except Jersey City are among the largest cities in the country. Jersey City, on the other hand, is second only to New York in population density with over 20,000 people per square mile. However, transit plays a much less important role in Los Angeles and Houston, also very large cities. The latter cities are characterized by fairly low population densities. They also are much newer cities in terms of when they became very large metropolitan centers than those which are notably transit-oriented. Thus, although city size is an indicator of transit use, population densities and the age of a city are equally important considerations.

The other variable factors encountered in the literature are mainly modifiers or alternate means of measure of those discussed above. For example, the land area variable used by Adams is employed in such a manner as to yield a population density. Adams, Hadden, and Kain all use variables dealing with the size and composition of the working force. Some of these merely are indicators of socio-economic status which, as discussed previously, has a high degree of correlation with the proportion of usage of public transit. Others have a more direct effect. Adams, for example, found that the size of the working force as a proportion of the total population was inversely related to the use of public transportation. Persons not in the working force include the unemployed, the aged, the infirm, housewives, and children. Except for children not yet in school, there is a tendency for all of these groups generally to be more dependent upon public transportation than are members of the working force. Consistent with this relationship is the finding by Hadden that married women living in the family unit who are members of the working force tend to travel by private automobile. However, in general higher proportions of females in the labor force lead to increased transit patronage according to both Hadden and Kain. Unquestionably, the relationship between transit usage and some socio-economic factors is not clearly understood, but the use of variables of this type by a number of researchers is indicative that such a relationship exists.

METHOD OF PROCEDURE

Sources of Data

Data utilized in this study were obtained from transit operators in 14 cities in Iowa and from various public sources. Transit companies were requested to supply information for the period 1950 through 1964 on the number of revenue passengers carried annually and the number of revenue miles of service provided in franchised intra-urban service during the same period. No information was requested concerning fare structures or revenues.

Records available to most transit operators did not include the entire period. In fact, only three companies were able to supply the data requested for 1950. However, usable data was made available covering 122 annual periods with at least 3 years from each of 14 cities.

Population figures were obtained from decennial censuses of population for 1950 and 1960. Populations for intervening years were estimated by straight-line interpolation. Increases in population of most cities in Iowa have been gradual and fairly uniform for the past two decades. Hence, any errors introduced by this method of estimation are believed to be of little consequence. However, a few urban areas in the state are known to be growing in population at an increasing rate. Fortunately, recent legislation has supplied the incentive necessary for those cities growing most rapidly to request special censuses. As a consequence, these were taken in more than 20 cities and towns in Iowa during the second half of 1965. Ten such communities are included within the service areas of transit companies which supplied data for this study. Populations for these cities for the years 1961 through 1964 were estimated by straight-line interpolation between the population figures from the decennial census of 1960 and the special census of 1965. For other cities, with the exception of Clinton, a rate of growth identical to that for the period 1950 to 1960 was projected to 1964. For Clinton, the population has been assumed to have remained constant since 1960. A special census was conducted in Clinton in 1965 but its results were never certified. A preliminary count which was announced in the press was 33,321 as compared to the 1960 census figure of 33,589. However, the average difference between the preliminary special census figures and the final figures was 0.645 percent in Iowa City, Burlington, and Ames, all comparable in size to Clinton. If the experience in Clinton were the same a final population count for 1965 would be 33,536 or essentially the same as the 1960 figure. For other cities which did not request a special census in 1965, it is reasonable to presume that growth rates have not increased since 1960. Hence, the method of projection which was used should produce results well within tolerable limits of accuracy.

Seven of the 14 transit companies included in this study serve an area which includes at least one incorporated suburb. In such cases, populations of a service area have been estimated by including all incorporated communities served by the transit operation. These cities with the suburbs included are as follows:

Des Moines; West Des Moines, Urbandale*, Windsor Heights*

Cedar Rapids*; Marion*

Sioux City; South Sioux City (Nebraska)

Dubuque; East Dubuque (Illinois)

Clinton; Camanche*

Iowa City*; University Heights*

Burlington*; West Burlington

* Ames plus the other cities and towns indicated above with an asterisk are those for which the results of special censuses in 1965 have been certified.

Data concerning the numbers of automobiles registered during the annual periods from 1950 through 1964 have been made available by the Motor vehicle Registration Division of the Iowa State Department of Public Safety. Automobile registration figures when related to population are not the same as automobile ownership. The number of vehicles registered during a year is approximately 10 percent greater than the number actually in use (23). The difference represents those cars which are scrapped or which have been involved in transfers of registration. Consequently, figures for automobile registration can be considered only as an indicator of automobile ownership which, in turn, influences the choice of travel mode. The factor used in this study is the ratio between population and auto registration or persons per car. However, records of vehicle registration in Iowa are maintained only for counties and not for individual cities. For this reason, the ratio has been calculated using registration figures and population for the counties in which cities served by transit are located. A majority of the population in all such counties resides in the community or communities served by transit. In 1960, Des Moines and its suburbs served by transit had 87 percent of the population of Polk County and the median such value for the 14 transit operations in this study was 66 percent. Consequently, a ratio of persons per auto calculated for the country may be considered to be closely indicative of the corresponding ratios for the cities included in this study.

The results of this investigation established a relationship between economic status and transit ridership. The median family income of residents of the central city served by a transit operation was used as the indicator of economic status for the potential patrons of that transit service. The most reliable estimate of this variable is believed to be that determined for 1949 and 1959 by a 20 percent sample taken as part of the decennial censuses of the United States for 1950 and 1960. To extend these estimates to other years, use was made of annual estimates of per capita income by states prepared by the Office of Business Economics of the United States Department of Commerce. These figures for Iowa were related to the median family incomes established for each city in 1949 and 1959 to indicate statewide trends. A further adjustment was effected by utilizing estimates made annually by _Sales Management_ of the mean effective buying income for each city included in the study. During the study period, the basis for the latter estimates was changed from households to consumer spending units to families. Because of these several changes in the basis for estimates of income, the values from _Sales Management_ are not easily related directly to the census figures. However, they are of value in indicating differences in trends of income from city to city. The values which were utilized for estimates of economic status thus were obtained by interpolating and extending the census figures for 1949 and 1959, adjusting these with annual statewide trends in per capita income estimated by the Office of Business Economics, and further adjusting these by the annual estimates made for each city by Sales Management.

The amount of use of public transportation is affected by the quantity of transit service provided. For this factor, the number of revenue miles operated annually has been adopted. Increases in the quantity of service are effected by increasing the frequency of service or by increasing the coverage with additional or extended routes. More frequent service tends to reduce waiting time for transit vehicles while increased coverage tends to reduce the average distance a patron must walk to reach a transit route. Hence, an increase in the quantity of service is also an improvement in the quality of service. To compare the quantity of service for different cities, annual revenue miles are divided by the total population of the area served. During the period included in this investigation, the number of revenue miles of service provided averaged about 10 miles per year per resident of the area served. However, there were substantial differences among the cities studied.

A further variable which significantly affects the usage of public transportation is the proportion of total population which is not in the labor force. The non-worker-worker ratio is a measure of this variable. This is defined as the ratio of persons not in the labor force to the number included in the labor force. These data for the central cities of each transit service area were obtained from the United States Censuses of Population for 1950 and 1960. Ratios for the years 1951 through 1959 were obtained by straight-line interpolation between those of 1950 and 1960. The same rate of change was projected for the years 1961 through 1964.

Population density has been described using the figures from the

Eighteenth Decennial Census of the United States, Census of Population, 1960. The population per square mile is reported for each of the central cities of transit service areas included in this study. Similar data were included in the 1950 census only for the five largest cities in Iowa. These differed little from the densities in 1960 for the cities included in this study. In Des Moines, for example, the population per square mile changed only from 3,242 in 1950 to 3,240 in 1960. Comparable figures are 2,846 and 2,789 for Cedar Rapids and 1,866 and 1,805 for Sioux City. It is apparent that this figure changes very slowly for the central cities of most urban areas. For this reason and because of the lack of reliable information regarding this variable at any other point in time, residential density throughout the period covered by this study was defined in terms of that given in the 1960 census. Such a figure is satisfactory if the corporate limits of the central city do not include significant areas of agricultural land and if there are not extensive areas of developed land at the urban fringes outside the corporate boundaries. A land-use survey for each city included in the study made in some detail would be necessary to define this variable more accurately. Since such more detailed information was lacking for some cities, the census data were used. Their inclusion substantially improved the correlation between actual and estimated values for transit patronage for most cities.

Development of the Model

A number of mathematical expressions were derived to investigate the effect of each of the variables used. Each expression described transit patronage in terms of some number of independent variables. An electronic digital computer was utilized to calculate each regression expression using the method of least squares. For each expression, a coefficient of multiple correlation and a standard error of estimate were determined. These are measures of the ability of an expression to reproduce accurately the historical data for actual transit usage in the cities included in the study.

Each expression used was in one of the three following general forms:

$$y = a + b_1x_1 + b_2x_2 + \cdot \cdot \cdot + b_nx_n$$

$$y = a + b_1\log x_1 + b_2\log x_2 + \cdot \cdot \cdot + b_n\log x_n$$

$$y = a \cdot x_1^{b_1} \cdot x_2^{b_2} \cdot \cdot \cdot \cdot x_n^{b_n}$$

In these expressions, y may be either the total number of revenue transit rides annually in a particular city or the number of rides per capita per year. The independent variables are x_1, x_2, etc., and a, b_1, b_2, etc., are coefficients to be determined by the regression analysis.

Data were available from only 4 cities for any period prior to 1955. The limited amount of data for these years tended to distort the analysis. Hence, the model was derived utilizing only data for the period 1955 through 1964. This included a total of 104 annual periods from 14 cities in Iowa.

In the derivation of some expressions, compound variables including more than one factor were used. Such a combination of factors was necessary to account for the different effects of some variables in cities of different sizes. For example, a given family income in a large city, because of the more extensive purchasing opportunities available in a metropolitan center, is associated with a lower socio-economic status than the same income level in a much smaller city. In respect to transit patronage, at least, this effect is related inversely to the logarithm of a city's population. Thus, an annual income of $5,000 for a resident of a city with a population of 100,000 is equivalent to an annual income of $4,000 for a resident of a city having a population of 10,000. The effect of the non-worker-worker ratio upon transit patronage also varies between large and small cities. This ratio must be multiplied by the logarithm of a city's population in order that its effect may be related for cities of different sizes.

RESULTS

The Model

The equation which best reproduces the historical data for transit patronage is as follows:

$$R_c = 33.25W^{2.345}D^{0.731}S^{0.852}E^{1.579}A^{-1.042}(\log P)^{0.156} \quad (1)$$

where R_c = revenue transit rides annually per resident of a transit service area

W = working force factor = $\frac{N(\log P)}{6.5}$

D = population density factor = $\frac{Q}{3000}$

S = service factor = $\frac{M}{10P_s}$

E = economic factor = $\frac{1700(\log P)}{I}$

A = persons per registered automobile in the county which includes a transit service area

$\log P$ = logarithm of P, base 10

P = population of the central city of a transit service area

N = non-worker-worker ratio for the central city of a transit service area

Q = density of population in the central city of a transit service area in persons per square mile

M = revenue miles of transit service provided annually

P_s = population of all incorporated places in a transit service area

I = median annual family income in dollars in the central city of a transit service area

This expression may be simplified as follows:

$$R_c = \frac{21.06N^{2.345}Q^{0.731}M^{0.852}(\log P)^{4.081}}{P_s^{0.852}I^{1.579}A^{1.042}} \quad (2)$$

Or, where R = total revenue rides annually = $R_c P_s$:

$$R = \frac{21.06N^{2.345}Q^{0.731}M^{0.852}P_s^{\,0.148}(\log P)^{4.081}}{I^{1.579}A^{1.042}} \tag{3}$$

Equation 1 has a coefficient of multiple correlation of 0.982 and a standard error of estimate of 2.96 rides per capita per year. Data which were used in the derivation of this expression as well as actual and calculated values of R_c are shown in Table 7 in the appendix.

The mean for 104 observed values of R_c is 26.29 rides per capita per year, so the standard error is 11.3 percent of the mean observed value. Origin-destination surveys made by the Iowa State Highway Commission in Des Moines, Cedar Rapids, Council Bluffs, Ottumwa, and Iowa City during the years 1962 through 1965 have shown that from 2.48 percent (in Iowa City) to 6.47 percent (in Des Moines) of all person-trips having both origin and destination within the urbanized area were made by public transit on a typical week day. Hence, in terms of a modal split, the standard error from the above model is equivalent to from 0.28 percent to 0.73 percent. This compares favorably with the results of other studies of public transit usage which have developed an expression for a modal split.

The zero order correlation coefficients between the variables in Equation 1 are indicated in Table 2. The first row gives the coefficients of correlation with R_c, the number of transit rides per capita per year. It may be seen that there is an extremely close correlation between R_c and S, the quantity of transit service which is provided. The other variables are correlated much less closely.

Table 2. Zero-order correlation coefficients for Equation 1

Variable	Correlation with variable S	W	logP	E	A	D
R_c	0.93	0.60	0.55	0.48	0.42	0.25
S		0.50	0.57	0.43	0.40	0.20
W			0.38	-0.08	0.04	-0.05
logP				0.15	0.12	0.09
E					0.55	0.13
A						0.46

Table 3. Zero-order correlation coefficients with data from Iowa City and Ames not included

Variable	Correlation with variable S	W	logP	E	A	D
R_c	0.90	0.46	0.55	0.44	0.75	0.54
S		0.35	0.56	0.38	0.67	0.41
W			0.37	-0.26	0.31	0.24
logP				0.12	0.20	0.15
E					0.63	-0.10
A						0.38

Of the 14 transit operations for which data were available and which were included in this study, two cities deviate significantly from the others in several demographic characteristics. These are Iowa City and Ames, both of which are sites of major universities. In both cities, the university enrollment represents about 40 percent of the total population. The presence of large numbers of students in dormitories tends to distort population densities. It also means that there are in use in both cities a considerable number of automobiles that are registered elsewhere. The effect that the presence of such a high proportion of students has on the correlations between variables may be seen by comparing Table 2 with Table 3. The latter shows the same correlation matrix as Table 2 except that data from Iowa City and Ames have not been included. A comparison of the two tables discloses that transit patronage correlates much more closely with both automobile ownership and population density if the two university cities are excluded. On the other hand, correlation with the non-worker-worker ratio is worsened somewhat. There is no significant change in correlations of R_c with the other variables obtained by excluding data for Iowa City and Ames.

The fact that A, the number of persons per auto, appears in the denominator in Equation 2 is inconsistent with its positive correlation as shown in Table 2. A positive correlation indicates that an increase in the number of persons per auto leads to increased transit patronage. On the other hand, an increase in A in Equation 2 would produce a lower value for R_c. This apparent inconsistency serves further to emphasize that automobile ownership is not independent of such factors as family income, population density, and the level of transit service. Inclusion of A in Equations 1, 2, and 3 produced a better correlation between calculated and observed values for R_c than if it were not included. This was also true of other expressions which were tested to describe the same relationships. However, for all such expressions in which A was used in combination with D, S, and E and which had coefficients of multiple correlation higher than 0.97, the apparent effect of A was inconsistent with its actual relationship to transit ridership. Because of the interdependency of the several variables, Equations 1, 2, and 3 may not be used with confidence to establish the extent to which changes in most variables taken singly will lead to changes in transit ridership.

A standard statistical test serves also to indicate that A contributes relatively less than most of the other variables to the accuracy of Equation 1. A two-tailed t test of the regression coefficients can furnish a measure of the likelihood that reductions in error in R_c are attributable to a specific variable. W, D, S, and E are all significant at levels better than 0.02 in Equation 1 as measured by this test while A is significant at a level of approximately 0.18. This implies that even though the inclusion of A yields a better estimating expression, relatively little confidence may be attached to its exponent when A is used in combination with the other variables in Equation 1. The t test also indicates that logP is not significant in Equation 1, although it is significant in Equations 2 and 3.

Elasticities

Elasticity may be defined as the ratio of the percentage of change in a dependent variable to the percentage of change in an independent variable when the latter is varied from a given value. In a logarithmic model such as that derived from this study the elasticity of the dependent variable, R_c, with respect to an independent variable is equal to the exponent of that particular independent variable.

Equations 1, 2, and 3 are not suitable for determinations of elasticity for variables which are correlated closely with several others. However, these will be used to investigate the effect of a small change in population, a variable which is relatively independent. It is necessary in this case to consider that a change in P leads also to a change in P_s. Data shown in Table 4, average values in 1964 for the 14 study cities, will be assumed for such a calculation.

Using Equations 2 and 3, R_c and R may be calculated respectively as 22.48 rides per person per year and 1,404,000 total revenue transit passengers per year. An increase of one percent in the population of the central city will cause R_c to decline to 22.39 rides per person per year but R will increase to 1,411,000 total rides per year. Thus, an increase in population of one percent, if it occurs entirely within the central city, will cause an increase in ridership of 0.51 percent. The elasticity of transit patronage with respect to population in this case is +0.51. On the other hand, if the same population growth occurred entirely in suburbs which were served by transit, R_c would decline to 22.30 rides per year per capita and the increase in the number of total revenue passengers annually

Table 4. Data for tests of elasticity, 1964

Variable	Average value
P = population, central city only	58,058
P_s = population, transit service area	62,435
logP = logarithm of P	4.763832
M = revenue miles of transit service	570,077
I = median family income in central city, dollars	7,535
Q = persons per square mile in central city	3,111
N = non-worker-worker ratio in central city	1.5016
A = persons per automobile in county	2.4257

would be only to 1,406,000. In this case, the elasticity of total ridership with respect to population is only +0.15. It is clear that dispersion of the population of a transit service area into the urban fringes adversely affects the importance of the role played by public transportation.

Single-Variate Expressions

A better indication of the elasticities of transit patronage with respect to some other variables is afforded by considering these variables singly. Figures 1, 2, and 3 show the relationships of annual per capita transit trips respectively with the service factor, persons per registered automobile, and the economic factor. In order to present transit use over a greater range of values, data for the period 1950 through 1954 have been included to the extent that they were available. Data for this period are summarized in Table 8 in the appendix. Also, to avoid the distortion caused by the inclusion of data for Iowa City and Ames, data for these two cities have been excluded in considering automobile ownership and the economic factor.

Service factor

An expression relating annual per capita transit ridership and the service factor is

$$R_c = 25.45S^{1.408} \quad (4)$$

The coefficient of correlation for this expression is 0.956. It implies that an increase of 1.0 percent in the number of annual revenue miles of service provided will lead to an increase of 1.4 percent in transit patronage. However, it is more nearly correct to state that decreases in transit patronage which have occurred since 1950 in the study cities have, on the average, been accompanied by greater decreases in service and that the relationship is as expressed in the above equation.

To illustrate this point, an investigation was made of the effects of increases in service which actually have taken place. Included in the data were 108 annual periods after the earliest year reported for each city. Revenue miles of service were increased in 36 of these periods scattered among 11 different cities. Half of the increases in service were accompanied during the same year by declines in patronage. In only 20 annual periods in 8 cities were increases in revenue miles sufficient in magnitude to offset population growth and cause increases in the service factors. The median increase in service factor was 2.55 percent for these periods. During 10 of these annual periods transit patronage increased

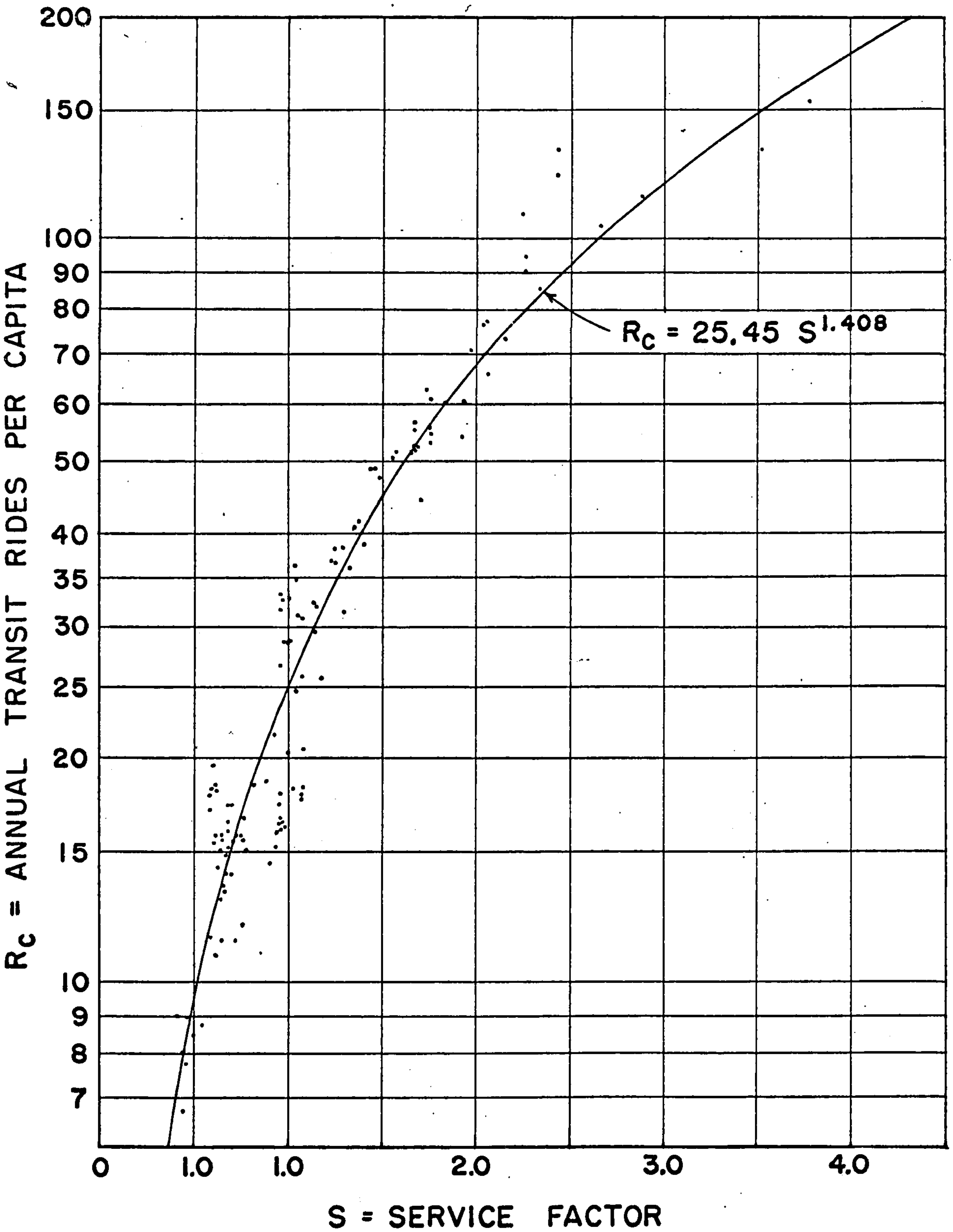

Figure 1. Relationship between transit usage and the service factor

and during 10 periods patronage decreased, the increases and decreases being of about equal magnitudes. It is clear that the effects of changes taking place in other variables have often been sufficient to offset the beneficial effects upon transit patronage which may have been anticipated from increases in the quantity of service provided.

Some studies have indicated that there often is an appreciable time lag between the introduction of a new or improved transportation service and its utilization by substantial numbers of new patrons. This is evidenced also in this study from experience with increases in the quantity of transit service. Of the annual periods during which transit service was increased sufficiently to cause an increase in the service factor, 17 occurred before 1964. For 11 of these 17 periods, an increase in patronage took place during the year following an increase in service.

Increases in service can take the form of more frequent service on existing routes, extension of service into areas not previously served, or entirely new services such as shopper's specials. The effect of the first method is to reduce headways between vehicles, decrease waiting times for passengers, and decrease total transit travel time. It is effective only on routes with proven passenger potential, however.

Extension of routes most frequently takes place into areas of new residential development. This generally has proven not to be effective where development has taken place first and then transit service is extended into the area. When this happens, residents form travel habits as the area is being developed. These habits, of course, do not involve the use of transit. The subsequent introduction of transit service is unlikely to induce significant changes in established patterns of travel.

However, a transit demonstration project in Memphis showed that if transit service were available while a subdivision was being developed, transit would play an important role in the travel habits of the residents (15). It follows, though, that revenues from this service are likely to be insufficient to offset costs during a formative period.

In fact, even if increases in patronage were always related to increases in service as indicated by Equation 4, the profitability of service increases would be questionable. Equation 4 indicates that where increases in service are relatively small, each additional revenue mile of service will generate 1.4 additional passenger fares. If, as is the usual case, variable costs of operation are greater than 1.4 times the average fare, the increase would not be profitable. Considering also the time lag associated with most increases in patronage which result from increases in service, it is obvious why transit operators more commonly adopt a reduction in service to effect improvements in their profit pictures.

Automobile registration

The relationship between automobile registration, expressed as persons per registered automobile in the county in which a transit operation is located, and annual per capita transit patronage is shown in Figure 2. An expression which describes this relationship is

$$R_c = \frac{A^{4.770}}{3.631} \tag{5}$$

The correlation coefficient for this expression is 0.833 indicating a fairly close relationship between the two factors. Iowa City and Ames were excluded for the derivation of this expression for the reason

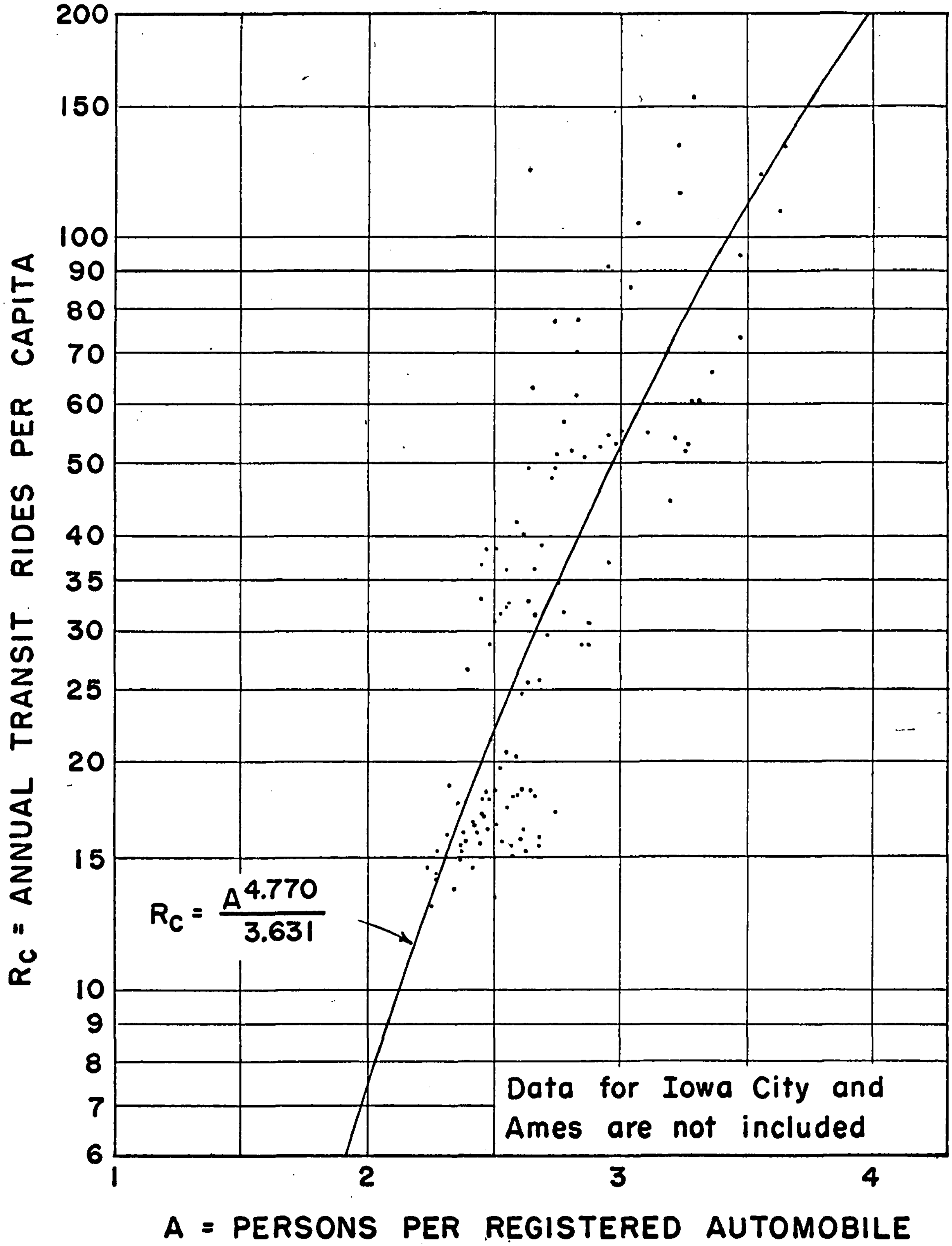

Figure 2. Relationship between transit usage and automobile ownership

discussed earlier.

The magnitude of the exponent in Equation 5 indicates that transit patronage is extremely sensitive to changes in automobile ownership. As shown in Table 4, there were an average of about 2.4 persons per automobile registered in 1964 in the 14 Iowa counties where the transit operations included in this study were located. According to Equation 5, this corresponds to a transit usage of 18.87 annual revenue rides per capita. It has been speculated that a ceiling for automobile registration in cities in Iowa might be about 550 autos per 1,000 population or 1.82 persons per automobile (22). Assuming that the relationship between travel habits of people in urban areas and automobile registration does not change and again referring to Equation 5, this figure for automobile registration corresponds to only about 3.15 annual revenue transit rides per capita. In view of the constant decrease in the number of persons per automobile, the implications of this relationship with transit patronage are not encouraging for those with hope for reversing the trend of decreasing transit usage.

Economic factor

Figure 3 presents the relationship between annual per capita transit patronage and the economic factor, $E = \frac{1700(\log P)}{I}$, where I is the median family income for the central city of a transit service area. This relationship may be expressed

$$R_c = 114.7 - 180.9E + 88.27E^2 \qquad (6)$$

which has a coefficient of correlation of 0.776, or

$$\log R_c = 0.4567 + 0.7576E \qquad (7)$$

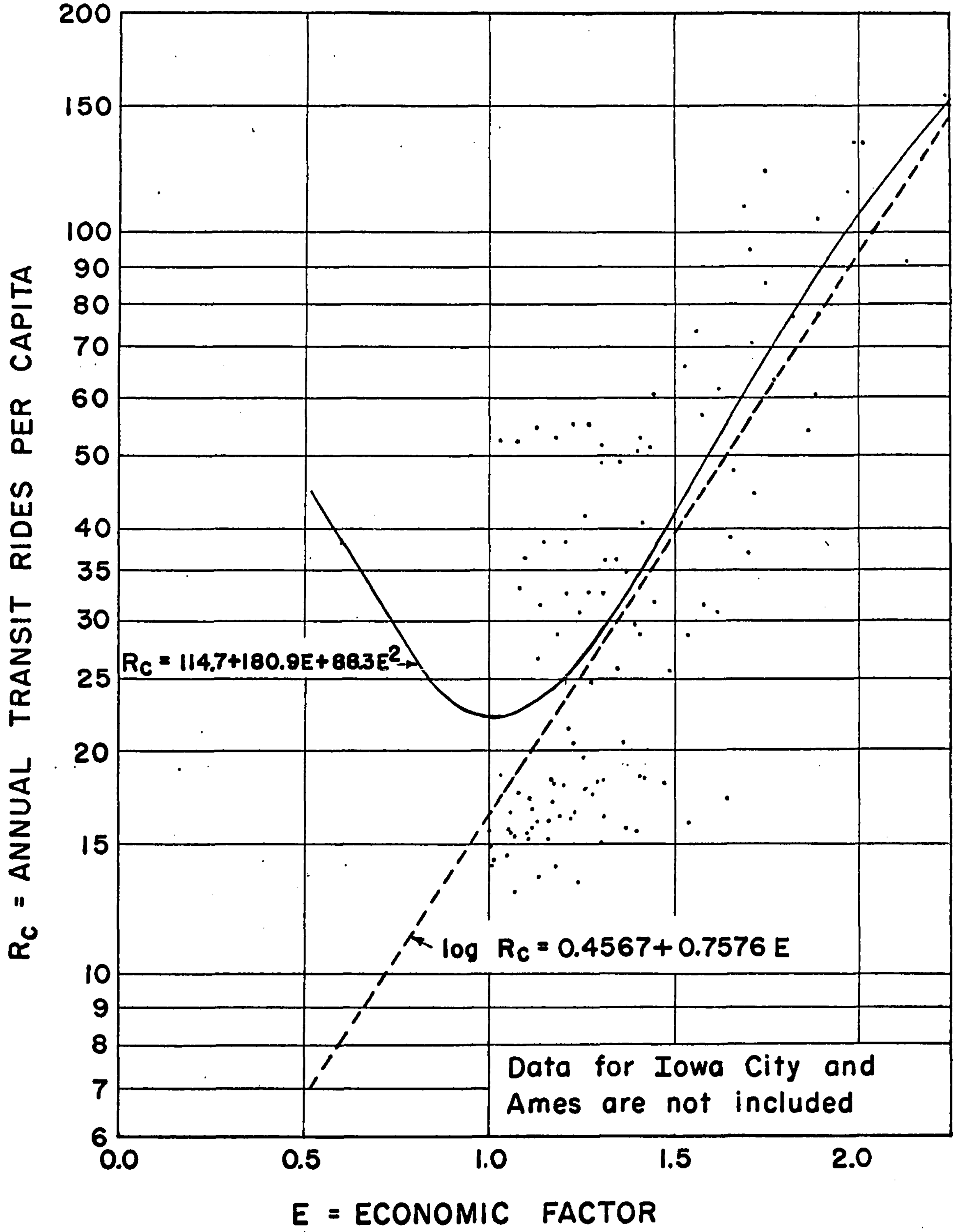

Figure 3. Relationship between transit usage and the economic factor

which has a coefficient of correlation of 0.741. Data from Iowa City and Ames also were excluded in the derivation of these expressions.

R_c in Equation 6 achieves a minimum at E = 1.025. This implies that as levels of family income higher than this are reached, transit patronage will tend to increase. For example, an economic factor of 1.025 corresponds to a median family income of about $8,900 in a city the size of Des Moines and to an income of about $7,200 in a city the size of Muscatine. There has been some experience to indicate that incomes higher than a certain level may occur together with higher levels of transit patronage, at least for certain types of travel. A survey of travel habits in cities of 100,000 population or more was made in 1961 by the United States Bureau of the Census for the Bureau of Public Roads (5). This survey showed that use of public transportation for home-to-work travel was at a minimum for family incomes of from $5,000 to $9,999. For this range of family incomes, 31.2 percent of home-to-work travel involved the use of public transportation for at least part of the trip. For family incomes of from $10,000 to $14,999, however, the use of public transportation increased to 36.6 percent. A further increase in family income to $15,000 or more led to a slight increase to 36.7 percent in the use of public transportation.

The effect of such a reversal of past trends as it relates to transit patronage in cities in Iowa may be illustrated by an example. Use of Equation 6 indicates that transit usage in a city with characteristics as summarized in Table 4 would have been 22.2 annual revenue rides per capita in 1964. The rate of increase in median family income in the 14 study cities is such that the mean value will be about $15,000 in 1984.

The mean population of these same cities will be about 78,000 in 1984, based on rates of growth from 1950 to 1964. This corresponds to a transit usage for 1984 of 41.5 annual rides per capita when Equation 6 is used for forecasting, an increase over 1964 of 87 percent. For comparison, the transit usage given in the Bureau of the Census study is only about 18 percent greater for family incomes of $15,000 than for family incomes of from $5,000 to $9,999.

On the other hand, use of the semi-logarithmic Equation 7 presents the projected relationship between transit patronage and median family income in a considerably different light. This expression indicates a decline in the use of public transportation accompanying any further decrease in the economic factor. Use of data from Table 4 with this expression indicates that use of public transportation in a city having the characteristics outlined previously would have been 18.7 annual transit rides per capita in 1964. By 1984, if changes in population and family income followed the pattern described above, this would decline to about 7.5 annual transit rides per capita.

The example above illustrates one of the dangers encountered in using mathematical expressions derived from historical data as a forecasting tool. In the case cited above, two expressions which reproduce historical data with a fair degree of accuracy produce vastly different results if used to project that data into the future. It is likely that neither projection is correct. One can only speculate as to which is more nearly correct.

Discussion of Individual Cities

The model which was developed varies among individual cities in its ability to reproduce accurately the historical data upon which it is based. Despite many apparent similarities, these 14 cities also have some distinctly individual characteristics. In this section, each city included in the study is discussed briefly considering the above two factors.

Des Moines

Des Moines is the largest city in Iowa. It is characterized by a fairly high economic factor when compared to other cities in the state, reflecting both its greater population and a fairly low median family income. Transit patronage has declined steadily from over 28 million revenue passengers in 1950 to under 7 million in 1964. Similarly, the quantity of transit service has decreased from year to year in a consistent pattern. The regularity of these declines has been such that every mathematical expression which was tested to describe patronage reproduced very well the historical data for Des Moines. The general expression, Equation 1, produces calculated values for transit ridership which vary from actual values by an average of 4.5 percent.

Cedar Rapids

In comparison with other cities in Iowa, Cedar Rapids has consistently low values for all the variables which are used as indicators of transit patronage except population. Consequently, transit patronage is quite low and is declining. Most of the expressions tested reproduced quite well the historical data for Cedar Rapids. The average difference between actual patronage and values calculated using Equation 1 is 5.4 percent.

Sioux City

Sioux City is characterized by high values for the non-worker-worker ratio, economic factor, and persons per automobile. Offsetting the effect of these variables is an extremely low population density. The location of Sioux City is such that the corporate boundaries include several pockets of undeveloped land in terrain which is too rugged for development. Mathematical expressions tested which included a population density factor correlated fairly well with the actual transit patronage but failed to reproduce accurately the very steep decline in ridership which has occurred in the past several years. On the average, values for transit patronage calculated by use of Equation 1 differ from actual values by 9.7 percent.

Dubuque

Dubuque is also located in terrain which is not favorable for urban development. However, unlike Sioux City, Dubuque has concentrated into a comparatively small area and has a high density of population. When compared to other cities in Iowa, it is characterized also by a high non-worker-worker ratio and a very high number of persons per auto. These factors have combined to maintain transit patronage in Dubuque at levels substantially higher than in any other city included in this study. Revenue passengers carried and revenue miles of service provided have remained fairly constant since 1956. Both were at slightly higher levels in 1964 than in 1957, for example. Use of Equation 1 yields predicted values for transit patronage which vary from the actual values by an average of 4.9 percent.

Council Bluffs

Values for all the variables used as indicators of transit patronage are higher in Council Bluffs than the average of the cities included in this study. Hence, use of public transportation on a per capita basis tends to be higher here than in any other study city except Dubuque. It has, however, declined steadily since 1958, the earliest year for which data are available. Estimation of patronage by using Equation 1 produces results which differ from actual patronage by an average of 5.3 percent.

Ottumwa

Ottumwa is the median city included in this study as regards population and it has a population density slightly lower than the average. All of the other variables have higher than average values. Consequently, transit patronage in Ottumwa is fairly high on a per capita basis in comparison with other cities in Iowa and is much higher than in other cities comparable in size to Ottumwa. The total number of revenue passengers has remained nearly constant at about one million each year since 1955. The mathematical model fails to reproduce accurately this constancy with an average error between actual and calculated values of 15.4 percent.

Clinton

Median family incomes in Clinton are quite high for a city of its size which leads to a low economic factor. The other variables tend to achieve values which are average for this study. As a consequence, transit patronage is fairly low. This transit operation changed ownership during 1960 so that data are available only for the years 1961 through 1964. The use of public transit in Clinton has remained essentially constant during this period. Equation 1 overestimates ridership by an average of 12.2 percent.

Iowa City

Iowa City possesses the extremes in variables which are characteristic of a university city and which were mentioned earlier. Most notable are a non-worker-worker ratio which is very low and a number of persons per auto which is quite high. Transit patronage also is very low but did not decline a great deal from 1960 through 1964. An average error of 13.7 percent is caused by the use of Equation 1 to estimate transit patronage in Iowa City.

Burlington

Burlington is characterized by a low non-worker-worker ratio, fairly low population density, and the lowest number of persons per registered automobile among the cities included in this study. Transit patronage thus tends to be quite low and is declining. The average error in the use of Equation 1 as an estimator of transit ridership in Burlington is 6.1 percent.

Mason City

The population density of Mason City is quite low and all other indicators are lower than the average for the cities included in this study. As a result transit patronage is fairly low. However, there were more revenue passengers carried during 1964 than during any previous year for which data are available, a period which starts in 1957. The mathematical model tends generally to overestimate transit patronage in Mason City with the average error being 17.6 percent.

Fort Dodge

Median family incomes in Fort Dodge are quite high. The other indicators also generally tend to cause transit patronage to be quite low, an exception being population density. Fort Dodge has the highest population density of any of the cities included in this study. However, Fort Dodge is also the only city for which inclusion of this variable appreciably worsened the ability of an expression to reproduce the historical data for transit patronage. The effect of its inclusion is to overestimate markedly the estimated number of revenue passengers in Fort Dodge. Equation 1 overstates this value by an average of 30.3 percent.

Ames

Like Iowa City, about 40 percent of the residents of Ames are university students. This leads to characteristics which generally are not favorable to appreciable amounts of travel being performed by means of public transportation. In addition, economic factors for Ames are lower than for any other city included in this study, a result of median family incomes which are quite high for a city in Iowa the size of Ames. As might be expected, transit patronage is very low being less than 7 annual rides per capita in 1964. Values estimated by the use of Equation 1 vary from actual values by an average of 7.1 percent.

Marshalltown

Marshalltown has characteristics which generally may be considered as unfavorable toward extensive use of transit. Its population density, however, is just slightly below the average and its non-worker-worker ratio is slightly above the average for cities included in this study. Transit patronage has been fairly low and although it exhibited an increase of almost 10 percent from 1958 to 1959, it has declined steadily since 1959. Estimation of the usage of public transportation by Equation 1 leads to values lower than actual by an average of 18.2 percent.

Muscatine

Muscatine is the smallest city included in this study. All of the variables used as indicators of transit patronage take on values which are quite low except for the economic factor. It follows that transit usage in Muscatine is quite low on a per capita basis. Although the service has changed little in the nine years for which data were included in this study, there has been a general decline in patronage. This varies from that estimated using Equation 1 by an average of 6.0 percent.

Transit in Iowa in the Future

In a previous section of this paper, the effects upon transit patronage of certain variables taken singly have been discussed. However, a very considerable interdependency of many of these variables is indicated by the correlations shown in Tables 2 and 3. Thus, it is more pertinent to consider the effect of changes in the independent variables collectively. For this purpose, a city possessing an average of the characteristics of the 14 cities included in this study will be considered.

Transportation planning very frequently considers a period of 20 years in the future. Hence, 1984 will be used as a date for investigation of the use of Equation 1 as a forecasting tool to estimate transit patronage in a hypothetical city in Iowa. Some projected data for use in this investigation are shown in Table 5. These estimates were made by hand fitting trend lines to the plotted data available for the period 1950 through 1964. They correspond to no particular city but rather are an average for the 14 cities in Iowa which are included in this study. Comparable data for 1964 are contained in Table 4.

Table 5. Data for forecasting transit usage, 1984

Variable	Projected average value
P = population, central city only	78,000
P_s = population, transit service area	88,000
logP = logarithm of P	4.8921
I = median family income in central city, dollars	15,000
Q = persons per square mile in central city	3,111
N = non-worker-worker ratio in central city	1.68
A = persons per automobile in county	1.82

A figure for persons per registered automobile projected on this basis was below 1.3, but it was assumed that some leveling off of automobile registrations will occur before there are 769 autos per 1,000 people. Accordingly, the ceiling of 550 autos per 1,000 people which was mentioned earlier has arbitrarily been imposed. No change has been assumed in population densities for 1984 as compared to 1964. This average city will have increased in population from 58,058 in 1964 to 78,000 in 1984. However, suburban population, which is increasing much more rapidly, will increase from 4,377 in 1964 to 10,000 in 1984. The non-worker-worker ratio will continue to increase.

The quantity of transit use implied by these characteristics is, of course, also dependent upon the quantity of transit service provided. This factor is controllable by those responsible for transit operations. Based on past trends, it is not likely that the number of revenue miles of service will increase from 1964 to 1984. If the absolute quantity of service were to remain constant, use of Equation 1 indicates a decline in transit patronage of about 31 percent from 1964 to 1984. This information is summarized as Condition 1984-1 in Table 6. On the other hand, if the revenue miles of transit service provided were to increase in direct proportion to the increase in population served (the service factor, S, remaining constant) the decrease in transit patronage would be only about 7.5 percent. This is the condition 1984-2 in Table 6.

Thus, the transit operator in this hypothetical city is faced with at least two rather unpleasant prospects for a time 20 years hence. On the basis that fares and unit costs of operation remain constant, these possibilities may be summarized as follows:

Table 6. Forecasts of transit usage

Condition	Revenue miles	Service factor	Annual rides per capita	Annual revenue passengers	Passengers per revenue mile
1984-1	570,077	0.648	11.07	970,000	1.70
1984-2	803,500	0.913	14.82	1,300,000	1.62
1964	570,077	0.913	22.48	1,404,000	2.46

1. Costs of operation in 1984 are equal to 1964 costs and revenues are reduced by 31 percent, the percentage decline in ridership of Condition 1984-1. Patronage is 1.70 passengers per revenue mile.

2. Costs of operation in 1984 are about 35 percent higher than in 1964 and revenues are reduced by 7.5 percent, Condition 1984-2. Patronage is 1.62 passengers per revenue mile. The exact extent of the increase in cost of operation would depend upon the relationship between fixed and variable costs. This condition assumes a 41 percent increase in service and hence in variable costs. The increase in total costs would be 35 percent, for example, if total costs are 85 percent variable.

A typical transit fare in Iowa currently is $0.25 while total costs of providing service generally average about $0.50 per revenue mile. Under these conditions, a level of patronage of two passengers per revenue mile is necessary if transit service is to be conducted profitably. However, four operations included in this study carried fewer than 1.9 passengers per revenue mile in 1964 and seven carried fewer than 2.1

passengers per revenue mile. These generally are companies which are losing money on their regular franchised service and are breaking even financially only on the strength of revenues from chartered services, school bus operation, and other special services. The possibilities posed by the forecasts to 1984 would seem rather clearly to call for substantial increases in fares during the intervening period if operating deficits are not to become extremely burdensome.

At this point it is appropriate to emphasize that the cost of transit travel has not been considered as a variable factor in this study. Demand for transit service has been considered inelastic in respect to cost. As mentioned earlier, the results of studies in Washington and Boston lend support to this assumption. A report by Stern considers transit fares and presents another point of view concerning demand elasticities (21). In this report, Stern states that demand for transit service seemed to be inelastic at lower fares while at higher fares it seemed to be elastic. This means that declines in patronage tend to follow increases in fares while increases in patronage tend not to result from decreases in fares. However, information is not available which would permit quantitative evaluation of the possible effect of this variable. Transit operators in conversation with the writer have all indicated that fare increases cause a slight but perceptible decline in patronage. Although a definite need is apparent for further research which relates transit patronage and fares, omission of transit costs as a variable is believed not to affect significantly the validity of the results of this study.

SUMMARY AND CONCLUSIONS

Reasonably accurate forecasts of the extent to which public transportation will be utilized for personal travel are required in connection with urban transportation planning. There are a number of demographic factors which have been shown previously to serve well as indicators of the likelihood that one mode of travel will be selected in preference to another. To make forecasts of transit usage, these factors must be identified and their role must be understood.

For this study, certain of these factors have been selected as variables and a mathematical model has been derived to describe transit patronage for cities in Iowa. Transit patronage may be expressed most conveniently in terms of an annual number of transit trips per capita. Alternatively, the model permits expression as a total number of passengers carried annually by a specific transit operation. The factors used in this investigation are as follows:

1. Revenue miles of transit service provided.
2. Population of the central city of a transit service area.
3. Total population of the transit service area.
4. Non-worker-worker ratio in the central city.
5. Median family income in the central city.
6. Persons per automobile registered in the county.
7. Persons per square mile resident in the central city.

This study utilized data from 14 transit operations in Iowa. The mathematical model which was derived from this data for the period 1955 through 1964 has a coefficient of correlation of 0.982 with transit patronage which was actually experienced. The standard error of estimate is 2.96 annual transit trips per capita.

The relationships expressed by this model may be seen to describe quite well the actual transit patronage in terms of the several indicators listed above. This should be considered true only in cities in Iowa. The same expression is not likely to describe this relationship accurately for cities in other states where characteristics may differ from those of urban areas in Iowa.

The model was derived to have general applicability for cities in Iowa. Obviously, more accurate estimation for a specific city is possible using only the historical data for that city. Also, for a particular city it may be possible to utilize effectively other variables in addition to those included in the general model. Parking availability is an example of a factor which might exert a significant influence on the choice between private automobiles and public transit for personal travel. The construction of new freeways which substantially reduce the effect of peak-hour congestion would tend to divert some travel from transit to private automobile. Various other factors might influence transportation uniquely in a given urban area and also ought to be considered. Generally, however, the variables listed above will serve adequately to describe the propensity to choose travel by public transit.

This model potentially is most useful as a tool for forecasting transit patronage at some time in the future. If reasonably accurate projections may be made for the several independent variables, a value for transit patronage can be obtained which is within the limits of accuracy required for travel forecasts.

Validity of this model as a forecasting tool is dependent upon the state of transportation technology. There have been no technical developments with application in cities in Iowa since 1950 which have improved the competitive position of transit travel. If anything, improvements in the design of passenger automobiles have tended to make this form of travel more attractive. It is conceivable that a radically improved system of urban transport could completely alter the relationships which previously have governed the selection of urban travel modes. Such a system could involve either large numbers of a new type of individual vehicles or a small number of some new form of vehicles for mass transportation. However, no such improvements in technology now appear likely to affect travel in cities in Iowa in the near future.

Since it is based on historical data, the model indicates a continuation of current trends in transit usage. Forecasts made with the model indicate that use of public transportation within the next 20 years will continue to decline, but that the rate of decline is decreasing. In an average city in Iowa, this decline is likely to be about 30 percent of the patronage in 1964. The extent of the decline may be influenced by the level of service provided. However, at best it appears that while several transit operations included in this study apparently were profitable in 1964, few are likely to be profitable in 1984. Although the interrelationship of the quantity of transit service and the fare structure with transit usage is not clearly understood, it is doubtful that continuing increases in fares combined with any level of service can generate additional revenues sufficient to offset the losses of transit patronage which appear inevitable. Since the profitability of many transit operations in Iowa currently is marginal at best, this infers that a different method of financing these operations will be necessary at some time in the future if these operations are to continue. Revenue from fares alone is likely to be insufficient to cover operating expenses in many cases. The program of capital grants authorized by the Mass Transportation Act of 1964 would assist transit operators to finance the acquisition of replacement equipment. This assistance might well be the difference in some communities between the retention of public mass transportation and the necessity for discontinuance of a hopelessly unprofitable operation. Other forms of financial assistance have been employed elsewhere and might also be necessary in Iowa.

Some measures which require public policy decisions may serve to arrest the anticipated declines in transit patronage. For example, in order to reduce pressures for costly measures intended to reduce congestion, a decision may be made not to construct parking facilities in a central business district. Similarly, construction of street improvements which alleviate congestion can be deferred. In both cases, travel by private automobile is discouraged and transit travel is made relatively more attractive. The same effect can be gained by the construction of freeway lanes on which transit vehicles are given preference. Moreover, transit operators have reported some success in attracting or retaining patrons by modernization of equipment and the introduction of improved services. Air-conditioned buses have been successful in this respect in some cities. If public transportation is to continue performing a necessary service in many cities, some such combination of public financial assistance, public policy support, and upgrading of the quality of service is essential.

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APPENDIX

Table 7. Data for analysis of use of public transportation in Iowa cities

Year	Population: Central city	Population: Service area	Annual revenue miles	Persons per sq. mi.[a]	Median family income[a]	Non-worker worker ratio[a]	Persons per auto[b]	Annual transit rides per capita[c]: Actual	Annual transit rides per capita[c]: Calculated
					Des Moines				
1955	193474	209119	4144498	3240	5253	1.2786	2.8241	70.49	70.95
1956	196575	213588	3722009	3240	5562	1.2865	2.8155	61.38	59.44
1957	199677	218059	3644653	3240	5735	1.2944	2.7812	56.69	56.46
1958	202779	222528	3504838	3240	6287	1.3023	2.7544	51.53	47.81
1959	205880	226998	3041870	3240	6436	1.3102	2.6273	40.49	42.99
1960	208982	231467	3040811	3240	6760	1.3181	2.5554	36.12	41.04
1961	212084	236439	2636664	3240	6948	1.3260	2.5637	32.58	34.71
1962	215185	241411	2594316	3240	7306	1.3339	2.5039	30.94	32.45
1963	218287	246381	2439534	3240	7678	1.3418	2.4846	28.68	28.73
1964	221389	251354	2402731	3240	8050	1.3497	2.4021	26.66	27.30
					Cedar Rapids				
1960	92035	102917	936550	2789	6967	1.3114	2.4883	21.39	19.64
1961	94337	106096	853428	2789	7258	1.3226	2.4729	18.19	17.17
1962	96639	109275	818469	2789	7639	1.3339	2.4237	16.70	15.66
1963	98941	112454	791989	2789	8032	1.3452	2.3765	15.54	14.41
1964	101243	115633	800361	2789	8450	1.3564	2.2797	14.03	14.07
					Sioux City				
1959	88642	95678	1087844	1805	5812	1.4777	2.7791	31.71	26.76
1960	89159	96359	1083837	1805	6042	1.4963	2.7075	29.66	26.44
1961	89676	97040	1037930	1805	6251	1.5149	2.6897	25.79	24.94

[a]For the central city only.

[b]For the county which includes the city indicated.

[c]For the entire service area.

Table 7. (Continued)

Year	Population Central city	Population Service area	Annual revenue miles	Persons per sq. mi.[a]	Median family income[a]	Non-worker worker ratio[a]	Persons per auto[b]	Annual transit rides per capita[c] Actual	Annual transit rides per capita[c] Calculated
1962	90193	97722	1003553	1805	6570	1.5335	2.6082	24.75	23.71
1963	90709	98402	980317	1805	6893	1.5521	2.5972	20.29	22.17
1964	91226	99083	958482	1805	7236	1.5707	2.5775	18.02	20.80
					Dubuque				
1955	53138	55028	1130306	4162	5257	1.4756	3.3494	65.92	65.02
1956	53832	55760	1078617	4162	5559	1.4963	3.2784	60.33	60.05
1957	54526	56492	947936	4162	5726	1.5170	3.2615	52.59	52.97
1958	55219	57224	938034	4162	6167	1.5376	3.2430	51.64	48.18
1959	55912	57956	970703	4162	6373	1.5583	3.1011	55.37	50.60
1960	56606	58688	1022725	4162	6634	1.5790	3.0093	55.40	52.52
1961	57300	59420	1048326	4162	6877	1.5997	2.9798	53.18	52.47
1962	57993	60152	1058831	4162	7216	1.6204	2.9447	54.70	50.87
1963	58686	60884	1027538	4162	7562	1.6410	2.9165	52.36	47.63
1964	59380	61616	1031612	4162	7916	1.6617	2.8134	52.06	47.26
					Council Bluffs				
1958	53599	53599	830288	3478	5748	1.5059	2.8641	50.70	48.23
1959	54620	54620	794445	3478	5967	1.5123	2.7380	49.15	45.93
1960	55641	55641	805553	3478	6209	1.5188	2.6440	49.23	45.32
1961	56662	56662	778123	3478	6439	1.5253	2.5963	41.66	42.40
1962	57683	57683	748273	3478	6744	1.5317	2.5066	38.20	39.59
1963	58705	58705	734105	3478	7085	1.5382	2.4811	38.15	36.47
1964	59726	59726	732303	3478	7445	1.5446	2.4450	36.85	34.22
					Ottumwa				
1955	33751	33751	414955	2920	4529	1.5655	2.9540	36.97	45.12
1956	33775	33775	350826	2920	4764	1.5781	2.8751	30.93	37.83

Table 7. (Continued)

Year	Population: Central city	Population: Service area	Annual revenue miles	Persons per sq. mi.[a]	Median family income[a]	Non-worker worker ratio[a]	Persons per auto[b]	Annual transit rides per capita[c]: Actual	Annual transit rides per capita[c]: Calculated
1957	33799	33799	335807	2920	5014	1.5908	2.8717	28.75	34.29
1958	33823	33823	341199	2920	5469	1.6034	2.8450	28.79	31.16
1959	33847	33847	348754	2920	5647	1.6161	2.7491	34.71	31.85
1960	33871	33871	345007	2920	5880	1.6287	2.6744	36.21	31.02
1961	33895	33895	338720	2920	6104	1.6413	2.6439	32.72	29.65
1962	33919	33919	330032	2920	6414	1.6540	2.5553	32.48	28.29
1963	33943	33943	323472	2920	6772	1.6666	2.5258	31.39	26.29
1964	33967	33967	324544	2920	7113	1.6793	2.4597	33.09	25.52
					Clinton				
1961	33589	35980	246142	3054	6662	1.5769	2.6295	15.18	17.63
1962	33589	36146	265991	3054	6992	1.5906	2.5797	15.53	18.09
1963	33589	36312	266465	3054	7334	1.6042	2.5258	15.70	17.46
1964	33589	36478	258954	3054	7694	1.6178	2.4436	15.68	16.61
					Iowa City				
1959	32820	33622	257716	4180	5769	1.3339	3.2180	15.03	16.63
1960	33443	34284	255990	4180	6044	1.3017	3.1338	11.96	14.78
1961	34848	35743	253649	4180	6246	1.2695	3.0803	11.29	13.11
1962	36253	37202	237046	4180	6577	1.2373	2.9245	11.29	11.12
1963	37657	38660	228100	4180	6872	1.2050	2.8098	11.41	9.67
1964	39062	40119	242472	4180	7182	1.1728	2.6788	10.84	9.21
					Burlington				
1955	31522	33609	471106	2703	4628	1.3393	2.6975	38.87	34.20
1956	31703	33885	436546	2703	4848	1.3396	2.6661	31.36	30.03
1957	31885	34161	400497	2703	5135	1.3399	2.6346	25.65	25.69
1958	32067	34438	372638	2703	5634	1.3402	2.5653	20.59	21.37

Table 7. (Continued)

Year	Population: Central city	Population: Service area	Annual revenue miles	Persons per sq. mi.[a]	Median family income[a]	Non-worker worker ratio[a]	Persons per auto[b]	Annual transit rides per capita[c]: Actual	Annual transit rides per capita[c]: Calculated
1959	32248	34713	375320	2703	5848	1.3405	2.5027	18.20	20.71
1960	32430	34990	376525	2703	6092	1.3408	2.4497	17.93	19.83
1961	32601	35256	349901	2703	6310	1.3411	2.4295	16.11	17.71
1962	32772	35521	336514	2703	6633	1.3414	2.3157	16.05	16.58
1963	32943	35787	332816	2703	6983	1.3417	2.2789	15.25	15.34
1964	33114	36052	326339	2703	7338	1.3420	2.2295	14.52	14.22
					Mason City				
1957	29843	29843	308995	2432	5403	1.4453	2.6479	18.19	22.85
1958	30110	30110	285200	2432	5805	1.4605	2.6231	16.23	19.64
1959	30376	30376	287100	2432	5979	1.4758	2.5492	17.39	19.82
1960	30642	30642	289200	2432	6224	1.4910	2.5067	16.51	19.43
1961	30908	30908	290460	2432	6438	1.5062	2.4681	16.26	19.17
1962	31174	31174	296580	2432	6769	1.5215	2.3796	16.08	19.10
1963	31441	31441	337833	2432	7114	1.5367	2.3458	17.63	20.42
1964	31707	31707	281700	2432	7437	1.5519	2.3132	18.57	16.87
					Fort Dodge				
1962	29056	29056	201268	4239	6868	1.5773	2.4605	17.09	21.85
1963	29384	29384	201154	4239	7210	1.5940	2.4224	16.41	20.97
1964	29713	29713	199851	4239	7584	1.6106	2.3679	14.89	20.10
					Ames				
1958	26158	26158	109638	3177	6002	1.4225	2.9756	8.98	8.81
1959	26592	26592	117077	3177	6191	1.4124	2.8648	7.97	9.01
1960	27003	27003	134588	3177	6548	1.4024	2.7968	8.47	9.30
1961	28568	28568	150076	3177	6722	1.3924	2.7435	8.75	9.58
1962	30132	30132	139187	3177	7050	1.3823	2.6039	8.96	8.44
1963	31697	31697	143387	3177	7392	1.3723	2.5431	7.78	7.91
1964	33261	33261	142131	3177	7756	1.3622	2.4402	6.79	7.30

Table 7. (Continued)

Year	Population Central city	Population Service area	Annual revenue miles	Persons per sq. mi.[a]	Median family income[a]	Non-worker worker ratio[a]	Persons per auto[b]	Annual transit rides per capita[c] Actual	Annual transit rides per capita[c] Calculated
					Marshalltown				
1956	21441	21441	129058	2963	5027	1.3854	2.6713	18.01	14.64
1957	21711	21711	129211	2963	5252	1.4122	2.6178	18.30	14.52
1958	21981	21981	129288	2963	5718	1.4390	2.6005	18.08	13.30
1959	22251	22251	129490	2963	5905	1.4658	2.5264	19.59	13.54
1960	22521	22521	129224	2963	6147	1.4926	2.4859	17.88	13.39
1961	22791	22791	133532	2963	6364	1.5194	2.4518	16.98	13.72
1962	23061	23061	139875	2963	6695	1.5462	2.3870	15.75	14.04
1963	23331	23331	139698	2963	7012	1.5730	2.3661	15.34	13.63
1964	23601	23601	145075	2963	7364	1.5998	2.2704	14.23	14.07
					Muscatine				
1956	20215	20215	140831	2413	4442	1.4667	2.7389	17.15	18.86
1957	20410	20410	135537	2413	4766	1.4837	2.6935	15.98	17.00
1958	20606	20606	131652	2413	5247	1.5006	2.6933	15.59	14.57
1959	20801	20801	131534	2413	5473	1.5176	2.6061	15.74	14.41
1960	20997	20997	132635	2413	5729	1.5346	2.5750	15.02	13.98
1961	21193	21193	136810	2413	5946	1.5516	2.5036	13.22	14.24
1962	21388	21388	143361	2413	6268	1.5686	2.4072	14.05	14.52
1963	21584	21584	138475	2413	6556	1.5855	2.3385	13.59	13.82
1964	21779	21779	134529	2413	6919	1.6025	2.2389	12.90	13.23

Table 8. Data for years 1950-1954

Year	Population: City only	Population: Service area	Annual revenue miles	Median family income	Non-worker worker ratio	Persons per auto	Annual rides per capita
				Des Moines			
1950	177965	186771	7048987	3998	1.2391	3.2878	153.04
1951	181067	191240	6722263	4497	1.2470	3.2210	133.24
1952	184168	195710	5647134	4549	1.2549	3.2235	115.15
1953	187270	200179	5317543	4734	1.2628	3.0659	103.76
1954	190372	204650	4743223	5144	1.2707	3.0331	85.65
				Dubuque			
1950	49671	51368	1248068	3963	1.3722	3.6469	133.29
1951	50364	52100	1259353	4574	1.3929	3.5597	122.14
1952	51058	52832	1183362	4719	1.4136	3.6289	108.99
1953	51752	53564	1214245	4695	1.4342	3.4811	94.77
1954	52445	54296	1170930	5164	1.4549	3.4817	73.39
				Ottumwa			
1952	33679	33679	616288	4094	1.5276	3.3125	60.27
1953	33703	33703	644161	4129	1.5402	3.2117	54.03
1954	33727	33727	574955	4483	1.5529	3.1939	44.59
				Burlington			
1950	30613	32227	729540	3596	1.3378	2.9534	90.63
1951	30795	32504	665250	4026	1.3381	2.8349	77.53
1952	30976	32779	664332	4206	1.3384	2.7412	76.92
1953	31158	33056	569628	4311	1.3387	2.6566	63.27
1954	31340	33332	498226	4614	1.3390	2.7346	47.59