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Traffic attraction to competing shopping centers

by

Stanley Lewis Ring

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Civil Engineering
Major: Transportation Engineering

Approved:

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For the Graduate College

Iowa State University
Ames, Iowa

1973

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INTRODUCTION

In Kansas City, during the mid 1920's, the Country Club Plaza appeared on the urban scene. With relatively little fanfare the nation's first planned, auto-oriented shopping center under unified management and ownership, had been created. The shopping center concept however was to remain relatively unnurtured for the next few decades.

The Central Business District (CBD), as it existed in the 1930-1940 era could really be considered an institution, and was intimately related to the social and economic life styles of American urban citizens. It remained relatively unchanged until aggressive commercial developers became active following World War II. Recognizing emerging affluency and universal personal mobility of the city dweller, the shopping center arose to challenge the position of the CBD as an institution.

Just as the pre-World War II CBD has been previously referred to as an institution, the modern shopping center has institutional aspects. People are attracted to shopping centers not only to shop, but to conduct business, for services, for recreational activities, for civic affairs, and perhaps just to be a part of the urban phenomenon.
The ubiquitous shopping center fills a multitude of roles on the urban scene.

Few economically viable urban areas in the United States are without one or more modern shopping centers.whose business is highly competitive and in most cases has played havoc with the CBD. The struggle to attract patrons has led to bigger and better centers and to more and more centers.

The Waterloo, Iowa urbanized area contains 113,100 persons according to the 1970 census (90). Also, a relatively high level of disposable income exists and certainly a high level of individual mobility exists in this urban area. In Black Hawk County there are 64,063 autos registered, or in a more meaningful form, there was one auto for every 2.1 persons. As a result of these conditions two developers have created modern regional competing shopping centers at opposite ends of the Waterloo urban area. In their short history the shopping center's attractiveness has to some degree hastened a decline in the effectiveness of an earlier strong CBD.

A relatively uncongested street system and minimal spatial separation results in a high degree of accessibility in Waterloo. Travel times are less than 25 minutes from any location in the urban area to either center. The relative size of the retail sales areas under discussion, in gross floor area are:

Waterloo CBD .... approximately 850,000 sq. ft.
Cedar Falls CBD .... approximately 300,000 sq. ft.
shopping center #1..... approximately 470,000 sq. ft.
shopping center #2..... approximately 723,000 sq. ft.

The unique condition of two similar, relatively large, modern shopping centers, competing for patrons who have equal opportunity to patronize either center, offers a laboratory for empirical study. An additional desirable feature is the variation in social, cultural, and economic characteristics of the population. The 1970 census tract characteristics must be studied to fully appreciate this observation. It can be seen that the predominant characteristics of different residential tracts may include: a university neighborhood, a high industrial employment area, ethnic group concentrations, and professionals. The clear stratification levels, of income and education for example, are readily apparent among census tracts.

Traffic engineers, planners, and land developers are faced with the difficult task of estimating the impact of a proposed shopping center on the community. The impact of a large traffic generator may have an immediate effect on the transportation facilities and the economic structure of a community. A large number of studies in many states have addressed this issue directly. The bibliography in this dissertation is by no means all inclusive, but is included as representative of marketing criteria and travel interactance concepts.

Various techniques for estimating travel, according to trip purpose, have been developed. Simple "factors" relating the number of vehicles per day to 1000 square feet of commercial floor area are in use in most states. The Illinois Section of Institute of Traffic Engineers (ITE) (48), and the Western Section of ITE (47) publications are excellent examples of very useful techniques. Other similar types of studies are from Minnesota (66), New York (31), Pennsylvania (37), and Connecticut (64).

More sophisticated formulas have been perfected as a result of transportation planning traffic analysis. In conjunction with origin and destination studies traffic engineers have been able to relate various types of trips to the characteristics of those persons making the trips. Trip generation and trip attraction equations have been developed for the purpose of estimating shopper trips. The National Cooperative Highway Research Program (NCHRP) Report 24 (68) provides an excellent discussion of the use of multiple regression analysis for determining shopping center trip generation equations. Fourteen independent variables were tested in a model representing data from 23 shopping centers. The U.S. Department of Transportation (DOT) publication "Guidelines for Trip Generation Analysis" (93) presents details on the techniques in current usage.

Closely allied to the determination of trip generating capabilities of various land uses is the distribution of these trips. Knowing that a group of people exist at one location (with disposable income and mobility), and that a number of retail attractors are available, is not satisifactory. Where these persons travel in performing their shopping activity is the ultimate answer desired. Their resistance to travel is a function of spatial separation and the attraction force at the destination. The aquisition of data from the Waterloo area and the subsequent analysis of that data was one of the objectives of this thesis.

The goal of this research is to formulate and test a mathmatical equation for estimating shopper trips to regional shopping centers. The dependent variable in this model form is observed trips to competing centers in Waterloo, Iowa. Independent variables are selected to explain trip generating characteristics of the populace, and the shopping center trip attraction phenomena. The mathmatical model developed will be of interest primarily to the traffic engineer rather than the marketing specialist.

LITERATURE REVIEW

Man has attempted to rationalize the interaction of group activities for many generations. Berry and Pred (8) review a number of these. An early attempt to rationalize the effect of distance (transportation) and rural land development was published in 1826 by Von Thunen (8). In his "Isolated State" concept the theoretical homogenous hinterland of a central city developed in a varying degree of intensity according to the spatial separation. The cost of transportation dictated the economic feasibility of a particular location's land use.

Walter Christaller (8) in later years applied a similar concept to development of a regional hierarchy of urban centers in an automobile oriented society. Hexagonal areas of influence developed around each urban center. The transportation routes form a hierarchy to succeeding orders in level of importance of the city. The smaller cities' linkage to succeeding order of size requires a higher level of transportation route.

Within an urban area, transportation bears a more important role in land use and development. The high degree of concentrated activity and high level of accessibility are readily apparent. A number of theories have also appeared relating urban development to transportation.

Ernest Burgess (8) attempted to explain the metropolitan structure by describing the area as comprised of a series of concentric zones. The first zone of the central city contains offices, banks, retail activities to name a few. The high land value requires a high level of accessibility. Successive concentric ring zones vary in land use and intensity in accordance with transportation requirements and other social-economic conditions.

Homer Hoyt (45) proposed the theory that development occurred in wedge shaped sectors. These were related to the axes of transportation corridors that focused on the Central Business District. Another concept hypothesized that the city form is a grouping of nuclei. Retail activities that benefit by proximity congregate to form shopping districts or shopping centers. But, because of competition in a finite market there is also a polarization force at work. Thus, the cumulative attraction effect takes place until competitive forces bring into existence another nucleous shopping center. Such is the case in Waterloo.

The Gravity Model Concept

Although these general theories of urban and regional development are useful in obtaining an overview, they do not quantitatively describe shopper trips. A more meaningful approach has been the adaptation of Newton's Law of Gravity developed in 1686. Newton stated that the gravitational force which acts between two bodies was in direct proportion to their mass, and in inverse proportion to the square of the distance between them.

By the 1820's it was suggested that Newton's Law of molecular gravitation might be applicable to social movements. E. G. Ravenstein

(73) first documented this so-called P/D relationship in 1885. He postulated an equation of the form:

$$M_{ij} = \frac{f\ (P_i)}{d_{ij}}$$

where:

M_{ij} = population migration movement from i to j

$f\ (P_i)$ = a function of the population at i

d_{ij} = distance from i to j.

In the late 1920's E. C. Young (102) came to the same conclusion as Ravenstein relative to the migration of people. He presented a deviation however in claiming that migration varied inversely as the square of the distance, whereas Ravenstein used no exponent for distance.

The first major application to retail activity was by W. J. Reilly (75) in 1929. Reilly's Law of Retail Gravitation states that two towns share the retail trade of a customer, located between them, in direct proportion to the population of the towns and inversely as the square of the distance from the customer to each town.

$$\frac{P_i}{{d_{xi}}^2} = \frac{P_j}{{d_{xj}}^2}$$

where:

P_i, P_j = population of cities i and j

d_{xi} = distance from city i to customer at x

d_{xj} = distance from city j to customer at x.

The modern gravity model originated with work by J. G. Stewart and G. K. Zipf. The expression was of the form:

$$F_{ij} = G \frac{P_i \; P_j}{d_{ij}^2}$$

where:

F_{ij} = force of interaction between i and j

P_i, P_j = population of area i or j

d_{ij} = distance between area i and j

G = a constant.

Zipf's model (104) did not include the d_{ij}^2 factor, but raised the entire term $\frac{P_i \; P_j}{d_{ij}}$ to a power. These models were tested measuring the interaction of pairs of cities by telephone calls, newspaper circulation, and bus passenger movements.

Alan M. Voorhees in a 1955 paper (95) presented the gravity model in a form suitable for explaining shopping trips:

$$T_{ij} = \frac{O_i \frac{S_j}{d_{ij}^x}}{\sum_{j=1}^{n} \frac{S_j}{d_{ij}^x}}$$

where:

T_{ij} = trips from zone i to zone j

O_i = trips produced or generated in zone i

S_j = attractive force of zone j

d_{ij} = travel time between zone i and zone j

x = an exponent to be determined by observation of existing trips.

In this study he noted that the travel time exponent varied according to the type of shopping trip. Where the pull of the shopping center was measured in square feet (attractive force), the exponent of three was used for convenience goods, and an exponent of two was used for shopper goods.

Other techniques utilizing the gravity principle have been presented to analyze shopping center trade areas. The Curtis Publishing Company (84) developed a modification of Reilly's Law of Retail Gravitation to outline the trade areas on a map. They determined that the breaking point (or 0.5 customer probability position) between two cities could be derived from Reilly's equation in the following form:

$$B_b = \frac{D_{ab}}{1 + \sqrt{\frac{P_a}{P_b}}}$$

where:

B_b = the breaking point in miles between city a and b, measured from city a

D_{ab} = the distance separating city a and b

P_a, P_b = the population of cities a and b.

Using this formula, and modifying the final results from field interviews, the Curtis Publishing Company developed a United States Area map of 498 market areas.

David L. Huff (46) noted the model used by the Curtis Publishing Company and developed a "Probablistic Model" for estimating shopping center trade areas. He observed that the 0.5 probability concept infers a fixed boundary circumscribing market potential. As this is untrue, he developed his model utilizing probability contours. Also, he substituted square feet of shopping center for population and used an empirically developed exponent for travel time. The model is of the form:

$$P(C_{ij}) = \frac{\dfrac{S_j}{T_{ij}^{\lambda}}}{\sum_{j=1}^{m} \dfrac{S_j}{T_{ij}^{\lambda}}}$$

where:

$P(C_{ij})$ = the probability of a customer at point i traveling to shopping center j

S_j = square footage at shopping center j (broken down into classes of goods)

T_{ij} = travel time between the customers residence and the shopping center.

λ = an empirical value reflecting the kinds of shopping trips.

The λ parameter was noted to be 3.191 for clothing and 2.723 for furniture.

In an allied study Walter G. Hansen (42) develops an "Accessibility Model" for explaining residential development. He notes that a controversy exists concerning the distance factor and the exponent in the gravity model. Where the early gravity models used distance and an exponent of 1, it has been empirically shown that the exponent may vary from 0.3 to 3.0. When empirical studies are examined according to trip purpose, the variation in exponent appears reasonable. Studies show that as the trip importance decreases the exponent increases. Whereas an exponent of work trips may be 0.9, an exponent of shopping trips may be 2.0. As the distance factor is in the denominator a decrease in the exponent means the distance factor is less restrictive. As Huff noted, this trip importance as measured by the distance factor exponent, can be differentiated at the shopper goods versus convenience goods level.

Hansen's concept of accessibility was expressed as:

$$ {}_1A_2 = \frac{S_2}{T_{1-2}{}^x} $$

where:

- ${}_1A_2$ = A relative measure of the accessibility of zone 1 to an activity in zone 2
- S_2 = the size of the activity in zone 2; i.e., number of jobs, people, etc.
- T_{1-2} = the travel time or distance between zones 1 and 2
- x = an exponent describing the effect of travel time between the zones.

Lakshmanan and Hansen (54) in a later paper, have developed a "Retail market potential model." The model is based on distributions of travel to large retail centers in the Baltimore area. In the development of the model they note that there is not a closed trade area, but rather a continuum of market orientation of shoppers. Shoppers in fact gradually develop knowledge of the total shopping attractors and in fact travel across boundaries. The model states that the sales potential of a center is directly related to its size and inversely related to a function of consumer travel distance.

$$S_{ij} = C_i \frac{\frac{F_{ij}}{d_{ij}^{a}}}{\sum_{k=1}^{m} \frac{F_k}{d_{ik}^{a}}}$$

where:

S_{ij} = retail expenditures of population in zone i spent in zone j

C_i = total retail expenditures of population in zone i

F_j = size of retail activity in zone j

D_{ij} = driving time between zones i and j

a = an empirical exponent.

The model was tested using Baltimore Metropolitan Transportation Study parameters and the origin and destination survey data.

The gravity model concept has been utilized and modified by transportation planners, geographers, retail market strategists, sociologists and other disciplines. Multitudes of studies can attest to the significance of its applicability. However, the assumptions on which the model is based and their relationship to the "real world" must be reviewed in the proper perspective. A most discerning view was presented by Gerald A. P. Carrothers (13) in a 1956 paper.

> As has been pointed out, the gravity and potential concepts of human interaction were developed originally from analogy to Newtonian physics of matters. The behavior of molecules, individually, is not normally predictable, but in large numbers their behavior is predictable on the basis of mathematical probability. Similarly, while it may not be possible to describe the actions and reactions of the individual human in mathematical terms it is quite conceivable that interactions of groups of people may be

described this way. This possibility is suggested by the phenomenon, observable in all the social sciences and in city planning, that people behave differently in groups than they do as individuals. But it is important to keep in mind that, although the use of anology in developing a concept may be attractive, it may defeat its purpose if strict and inflexible adherence is insisted upon. In this case, a fundamental difficulty arises from the different nature of the two basic units of measure involved: the individual human being can make decisions with respect to his actions, while the individual molecule (presumably) cannot. This does not imply that interaction of humans in large numbers cannot be described mathematically, but it does mean that the threshold where the power in individual decision-making critically affects the results must be determined before the concepts can be broadly applied in science.

The various gravity concepts of interaction are only a few of the many theoretical concepts being applied to urban and metropolitan structure. Even though the present state of development of the gravity concepts is inadequate, nothing in them is inherently inconsistent with other theoretical formulations. A great deal of empirical investigation is needed (and is currently in process) before the theories can be directly applied to problems of urban and metropolitan development.

Retailing Theories

Retail Marketing strategists are generally concerned with determining trade areas in a location analysis situation. The empirical considerations of population density, income, and spatial factors are inherent in market analysis. White and Ellis (100) propose a "systems theory model" for predicting supermarkets' yearly sales. Based on a study of 24 Canadian supermarkets a number of linear regression equations were developed with three system components:

1. Origin of supermarket trips:

$$Y_i = 52 \times C_i \times P_i$$

where:

Y_i = yearly flow of grocery dollars from area i

C_i = food cost per week per capita in area i

P_i = population of area i.

2. Roadway links connecting origin and destinations:

$$X_{ij} = R_{ij} Y_{ij}$$

where:

X_{ij} = pressure required to cross the link from node i to node j

R_{ij} = resistance to flow on link i j.

Y_{ij} = yearly net flow of supermarket shopping dollars through link i j.

3. Destination (supermarket)

$$Y_j = A_j X_j$$

where:

Y_j = yearly sales of supermarket j

A_j = attraction of supermarket j

X_j = propensity to shop at supermarket j.

The model developed has 143 components measuring variables, and 64 nodes. Given the availability of the mass of input data required, the model undoubtedly can be programed to reproduce the system. And if the effect of changes on system components are desired these can be predicted and the effects evaluated. The disadvantage of a complex system of this form is the usual lack of detailed information available relative to sales. Also, this model is based on the unique single activity type of grocery purchase store.

Ellwood (27) proposes a modified application of Reilly's Law of Retail Gravitation to estimate the potential pulling power of a new shopping center location. He calls attention to the fact that a new store generally does not create new retail business, but rather redistributes trade among all the trading places available. Also, that shopping center trade areas do overlap, but that certain classes of merchandise have very extensive pulling power. However, where similar goods and services are available at competing centers there is a breaking point of equal attraction.

Brunner and Mason (12) have studied driving time as an influence on shopping center preference. They note that previous studies have suggested that consumers generally are reluctant to drive more than 20 minutes to patronize a shopping center. Analysis of data from five shopping centers in Toledo, Ohio, indicates a primary trading area that is limited to 15 minutes driving time. Between 70 percent and 76 percent of all shoppers resided within 15 minutes driving time. They also noted that the largest shopping center containing three major department stores attracted 76 percent of its shoppers from a 15 minute driving time. Thus the powerful shopper goods attraction of department stores was insufficient to overcome the pattern. The results of the study are presented in Table 1.

Table 1. Cumulative percentage of customers by driving time increments (Toledo, Ohio)

Shopping center	Driving time in minutes 0-5	0-10	0-15	0-20
A	17.7	48.9	76.4	81.7
B	31.3	53.0	76.5	87.2
C	31.7	54.1	72.5	84.6
D	27.5	58.5	72.7	85.8
E	37.5	59.4	70.1	81.6

Nelson (70) calls attention to the fact that business location criteria takes into consideration three elements: market, labor and supply. In the case of shopping center location the retailer must be accessible to people and site selection criteria is as a consequence virtually all market-oriented. Thus, the variables of population, income, and accessibility are prime logical candidates in a model to represent causal relationships for travel to shopping centers.

In addition to the fundamental market analysis concept, the author formulates other site selection criteria based on retail management principles. Shopping centers have varying degrees of attractiveness to consumers. Nelson lists eight principles to be applied to specific site selection analysis. Two of these principles are major contributions to retail management, and represent a measure of shopping center marketing success.

Nelson's Theory of Cumulative Attraction states: "A given number of stores dealing in the same merchandise will do more business if they are located adjacent or in proximity to each other than if they are widely scattered." When certain types of stores cluster they become in effect a "center" and the total trading area is enlarged. An increase in size of a major shopping center has more than a straight line relationship to the market area.

Nelson's Rule of Retail Compatibility states:

> Two compatible businesses located in close proximity will show an increase in business volume directly proportionate to the incidence of total customer interchange between them, inversely proportionate to the ratio of the business volume of the larger store to that of the smaller store, and directly proportionate to the sum of the ratios of purposeful purchasing to total purchasing in each of the two stores.

These relationships are expressed mathematically as:

$$V = I\ (V_s + V_l) \times \frac{V_s}{V_l} \times \left(\frac{P_l}{V_l} + \frac{P_s}{V_2}\right)$$

where:

V_l, V_s = dollar volume of larger and smaller store

P_l, P_s = purposeful dollar purchasing in large and smaller store

V = increase in total volume in two stores

I = degree of interchange.

These principles are set forth here to illustrate the marketing researchers' attempt to quantify the varying degrees of shopping center attractiveness. Not only are merchandising techniques and promotional activities important, but fundamental concepts of store sizes and groupings play a role in attracting shoppers.

The effect of design can be considered an amenity variable. As Nelson (70) states, the center must be designed to be more than just a group of stores with free parking. The most important amenity is the creation of facilities that will ensure safe, uncongested, readily understandable ingress and egress from the street system to the parking space. A shopping center with difficult entrance and exits, unsafe internal roadways, and parking lots that are visually unappealing has a definite decreased attractiveness factor in terms of competition.

The CBD has an inherent advantage in view of the complex of amenities available. Governmental facilities, entertainment, restaurants, and cultural facilites are a few. The shopping center, according to Nelson, competes with glamour. New store fronts, fountains, art, plantings, music, environmentally controlled malls, as well as a mix of restaurants, rest rooms, and resting places are necessary. They should not be considered "extra", but as necessary to replace the older shopping district's amenities.

The literature is replete with empirical principles of consumer response. These principles reflect the phenomenon of group action. The preference of the individual for factors of attraction and resistance to travel has been aggregated based on years of studies. A few typical empirical regularities are noted:

1. Shoppers move toward the dominant center.

2. Shoppers will not go thrcugh one trading center to get to another with equal facilities.

3. Shoppers will patronize the closest center with equal facilities.

4. Shoppers tend to follow traditional circulation patterns.

5. The proportion of consumers patronizing a given center varies with the distance from the center.

6. The proportion of the consumers patronizing various areas varies with the breadth and depth of merchandise offered.

7. The distance that consumers travel to various centers varies for different types of product purchases.

8. The pull of a given center is influenced by competing centers.

Review of the literature relative to human interactance concepts, marketing criteria, and especially the gravity model concept, has been conducted to provide a base for an analysis and interpretation of the Waterloo data. Development of a model representing measured comsumer's travel to the competing Waterloo shopping centers follows. The relevance of this research can best be supported by a quote from Brunner and Mason (12):

> Perhaps the most surprising thing about our knowledge of planned shopping centers is the gap of quantative information available on the subject. The literature abounds with judgements, insights, and discussions on the significance of population, household income, and similar variables; but presentations of a statistical nature are few and far between.

The underlying purpose of the literature search was to identify variables of concern, concepts, and techniques relative to synthesizing travel to shopping centers. As has been noted, certain fundamental hypotheses that have been presented in the literature have received recognition and acceptance as principles. It is the purpose of this study to identify those variables that appear suitable for synthesizing Waterloo shopper trips; to formulate a model and to test and analyze the various components; and finally to refine those variables selected to achieve the most significant model.

As a result of the literature search it was determined that data would be required in the following areas:

1. Social economic characteristics of the various census tracts from which shoppers originate.
2. Characteristics of each shopping center that would represent its ability to attract shoppers.
3. A record of shopper trips to each center for the same time period.
4. Identification of each local shopper's home address.
5. Travel time and/or distance separating the shopper from the center.

RESEARCH PROCEDURE

Social and Economic Characteristics

The 1970 census of population and housing (90) provided basic information for aggregated shopper characteristics. This report contains numerous statistics on population and housing characteristics. Some of the statistics, such as population, are based on 100 percent data and other statistics are based on 20 percent and 15 percent samples.

The Bureau of the Census has subdivided each Standard Metropolitan Statistical Area (SMSA) of the United States into small sub areas. These small census tracts are selected to delineate relatively homogeneous uniform characteristics of the population, economic status, and living conditions. Tract boundaries have been established in conjunction with local committees and Figure 1 identifies the Waterloo-Cedar Falls tracts. Figure 2 identifies the remaining Black Hawk County tracts.

The address of vehicle registrants in a rural area was simply a rural postal route. Postal routes were obtained from each post office and delineated on a map. However, it became apparent later that the postal addresses overlapped the census tracts. In many cases the adjacent census tracts had widely differing characteristics and caused a high degree of uncertainty as to an individual shopper characteristic. As a consequence rural shopper data were not used in the model analysis.

From the multitude of social-economic characteristics available in each census tracts the following were considered for detailed analysis:

1. population
2. income
3. ratio of renter to owner occupied housing
4. ratio of nonworkers to workers

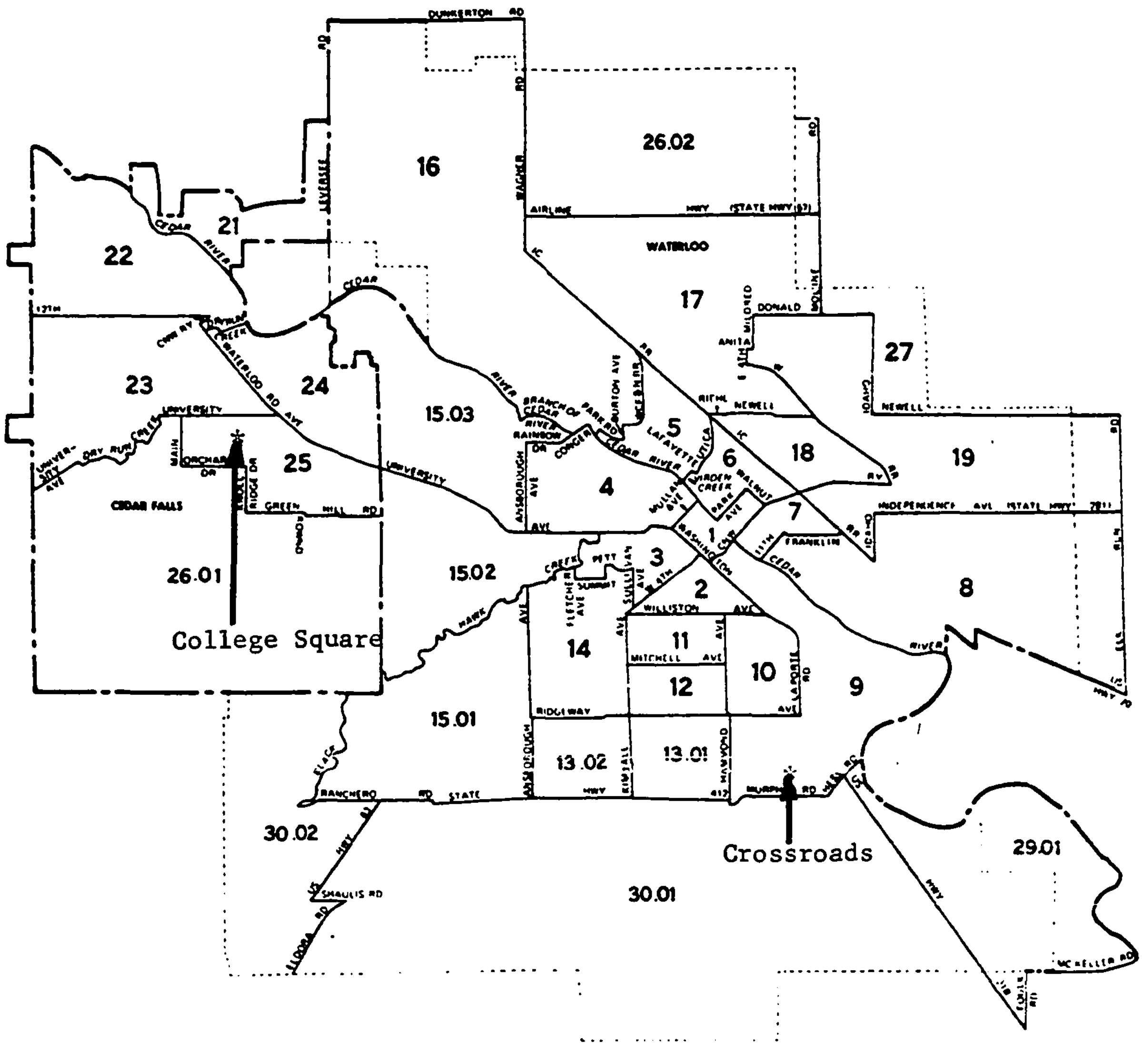


Figure 1. Waterloo, Cedar Falls census tracts

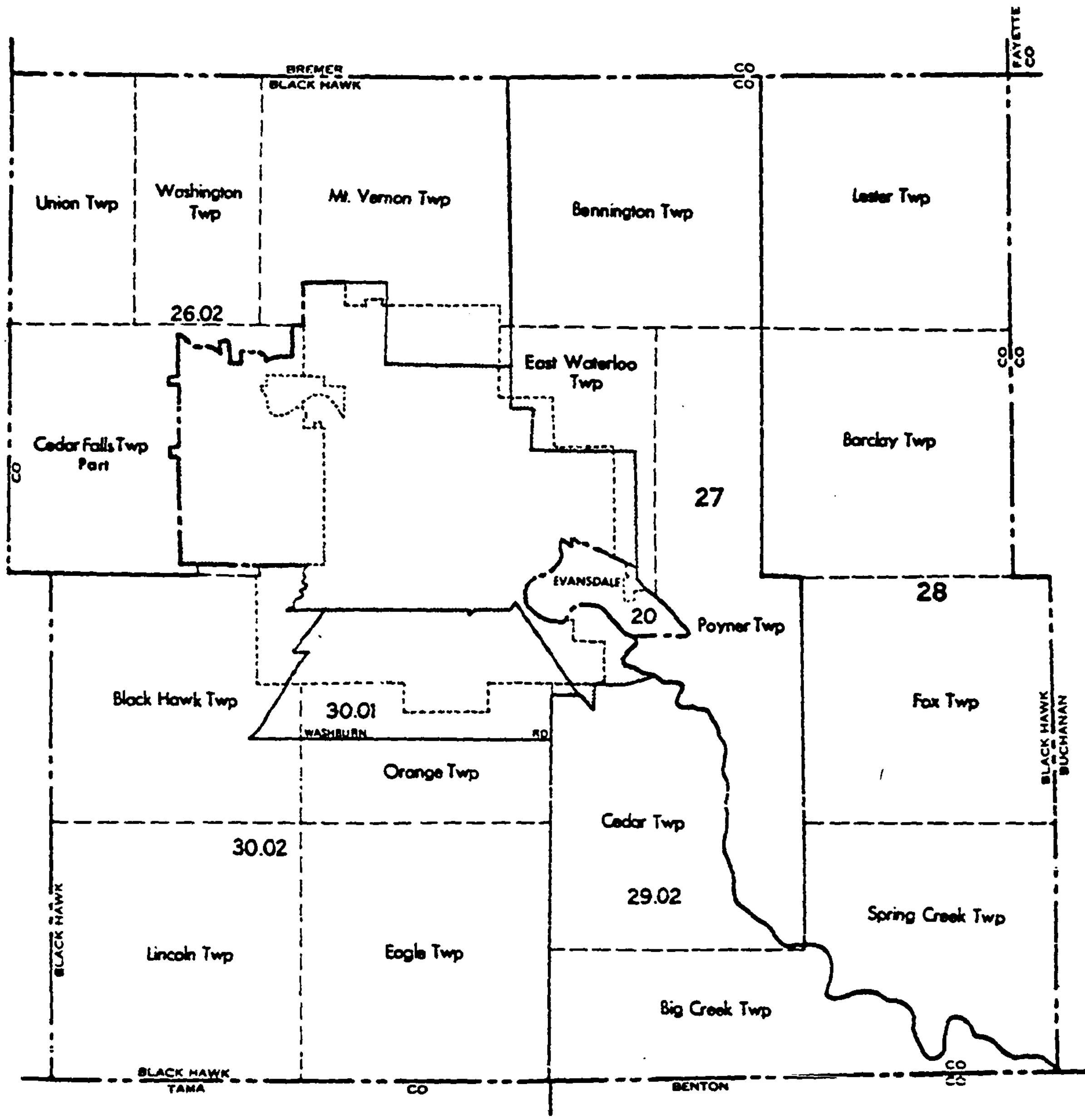


Figure 2. Other Black Hawk County census tracts

5. percent Negro
6. house value
7. percent of poverty families
8. percent of college educated
9. persons per household
10. changing place of residence factor
11. autos per household.

Table 2 identifies these data for individual census tracts of concern.

College Square Shopping Center

The College Square shopping center is located on US 218 in Cedar Falls. As can be noted from Figure 3 the location provides ready access to the street and highway system of the metropolitan area. Residential distribution for the entire urban area is graphically illustrated in Figure 4. Travel times from any location in the metropolitan area were subsequently determined to be less than 30 minutes.

The General Development Corporation of Des Moines constructed the center in 1969. The location on six-lane US 218 provides shoppers with an opportunity to take advantage of the extensive commercial development that has occurred along this route. The Blackhawk Village shopping center is immediately adjacent on the east.

College Square center occupies 60 acres of land with 471,000 square feet of total building area. Fifty-six stores with nearly 800 employees offer sales and services in 388,000 square feet of retail sales area with two major department stores providing the nuceus for shopper attraction. An enclosed air conditioned mall with fountains, furniture,

Table 2. Selected social and economic characteristics for Waterloo, Cedar Falls and Evansdale

Census tract number	Population	Median[a] income	Ratio of renter to owner occupied housing	Ratio of non-workers to workers	Percent Negro	Median[b] value of owner occupied housing	Percent families below poverty level
1	951	3400	34.45	1.45	4.1	10	33.3
2	3909	8388	0.86	1.63	0.1	13.5	10.7
3	3833	8206	1.58	1.48	0	13.3	10.8
4	2403	8688	0.27	1.60	0.2	12.1	4.8
5	1926	8153	0.25	1.75	5.5	10.9	12.3
6	2638	5371	2.22	2.61	41.2	10.0	19.1
7	2702	7143	1.16	1.85	25.6	8.8	16.9
8	4418	8133	0.29	1.70	2.0	9.4	11.8
9	2055	7162	0.83	2.34	0.2	9.1	18.3
10	5026	11070	0.11	1.25	0	17.0	2.9
11	3489	10370	0.25	1.45	0	15.4	3.0
12	2998	12397	0.15	1.08	0.1	19.5	3.6
13.01	2783	13269	0.27	1.26	0	24.9	1.9
13.02	1686	17281	0.41	1.34	0	33.5	4.0
14	5828	12846	0.13	1.49	0.1	21.1	4.2
15.01	1694	11816	0.10	2.29	0.1	22.3	2.2
15.02	4024	9866	0.15	1.80	0.5	16.4	3.6
15.03	4600	11588	0.15	1.47	0	19.0	4.3
16	3811	9407	0.15	1.67	0	14.7	4.8
17	6249	9538	0.20	1.73	20.2	12.7	5.9
18	2478	7457	0.26	2.31	89.9	9.5	25.6
19	3118	8791	0.23	2.08	31.6	12.3	9.7
20	6066	9170	0.26	1.84	0	10.4	6.4
21	958	8097	0.21	1.47	0.4	8.0	10.0
22	6663	10656	0.44	1.49	0.1	17.8	6.0
23	12876	9459	0.93	1.43	0.5	18.9	8.3
24	4924	12156	0.11	1.36	0	21.2	3.5
25	3113	12649	0.05	1.60	0	22.9	6.8
26.01	1063	12505	0.24	1.91	0	24.0	2.0
26.02	442	11154	0.16	1.38	1.8	18.4	3.5
27	48	11154	0.75	1.28	10.4	21.3	3.5
29.01	1501	10726	0.05	1.95	0	19.4	5.0
30.01	815	10757	0.28	1.50	0.2	25.5	4.5
30.02	108	13800	0.29	2.08	0	27.7	16.7

[a]In dollars.

[b]In thousands of dollars.

Table . (continued)

Census tract number	Percent of persons 25 years and older with a college education	Persons per household	Percent of persons 5 years and older living in a different house 5 years ago	Autos per household
1	5.78	1.30	58.1	0.43
2	6.88	2.67	49.4	1.09
3	4.65	2.45	59.1	1.09
4	0.98	2.95	34.5	1.28
5	2.86	2.76	43.1	1.07
6	2.06	2.53	50.1	0.73
7	3.11	2.98	51.0	0.93
8	1.67	2.94	40.2	1.25
9	1.72	2.91	41.6	0.97
10	4.20	3.24	32.5	1.55
11	8.77	2.93	37.4	1.31
12	12.87	3.18	38.9	1.54
13.01	21.12	3.42	62.2	1.69
13.02	29.47	2.79	53.5	1.72
14	23.49	3.14	40.3	1.57
15.01	13.27	3.79	61.4	1.82
15.02	2.42	3.73	42.4	1.46
15.03	11.94	3.58	44.6	1.57
16	4.29	3.29	45.1	1.33
17	2.99	3.44	28.8	1.30
18	2.07	3.58	26.9	1.02
19	7.35	3.45	38.9	1.28
20	1.91	3.76	29.0	1.56
21	0.92	2.71	63.8	1.36
22	19.68	2.99	48.8	1.44
23	26.89	2.87	74.3	1.46
24	20.45	3.27	34.9	1.74
25	26.28	3.89	37.5	1.82
26.01	19.32	3.48	70.5	1.41
26.02	16.88	3.48	35.0	1.77
27	16.88	3.43	99.9	1.77
29.01	4.12	4.08	63.9	1.64
30.01	11.66	3.62	68.6	1.54
30.02	0.45	4.00	88.6	1.20

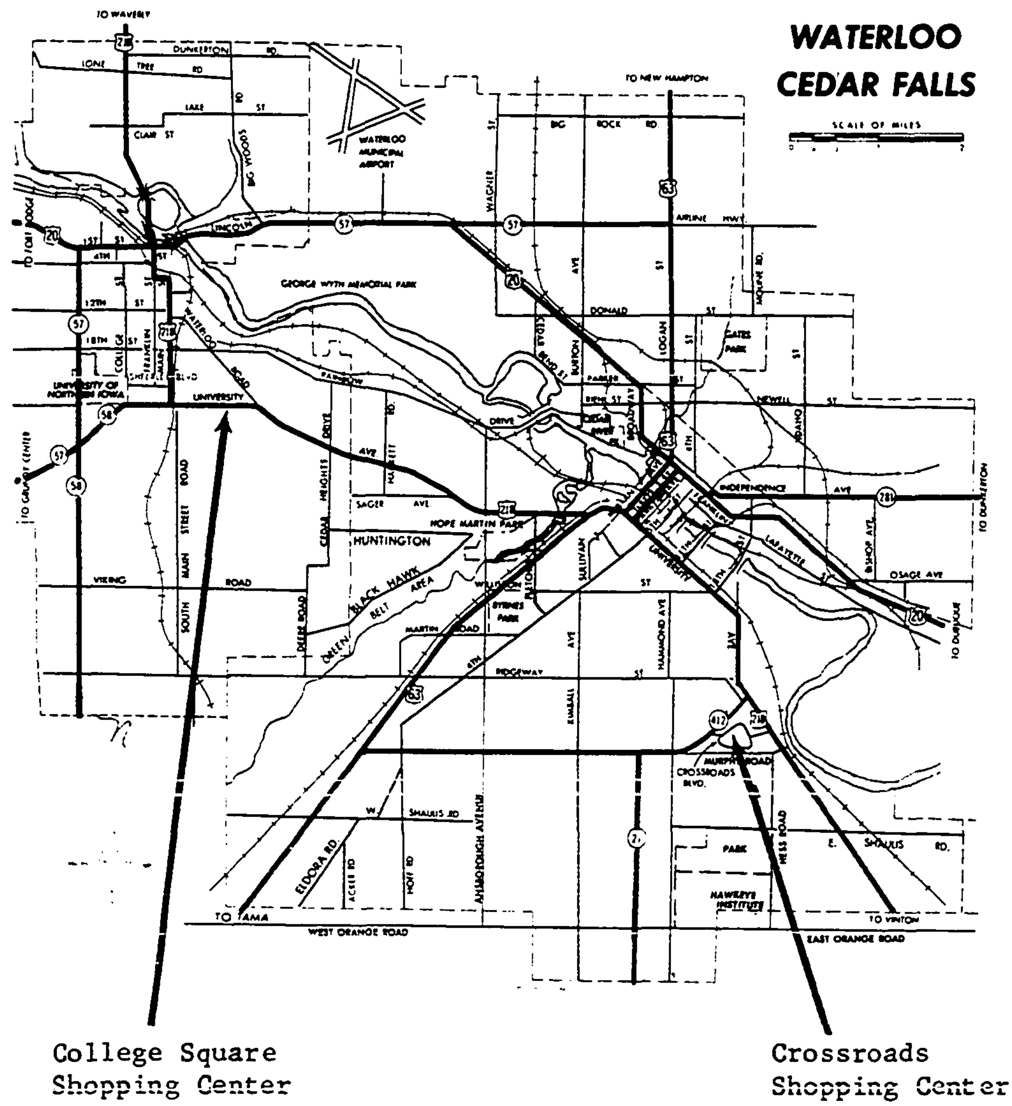
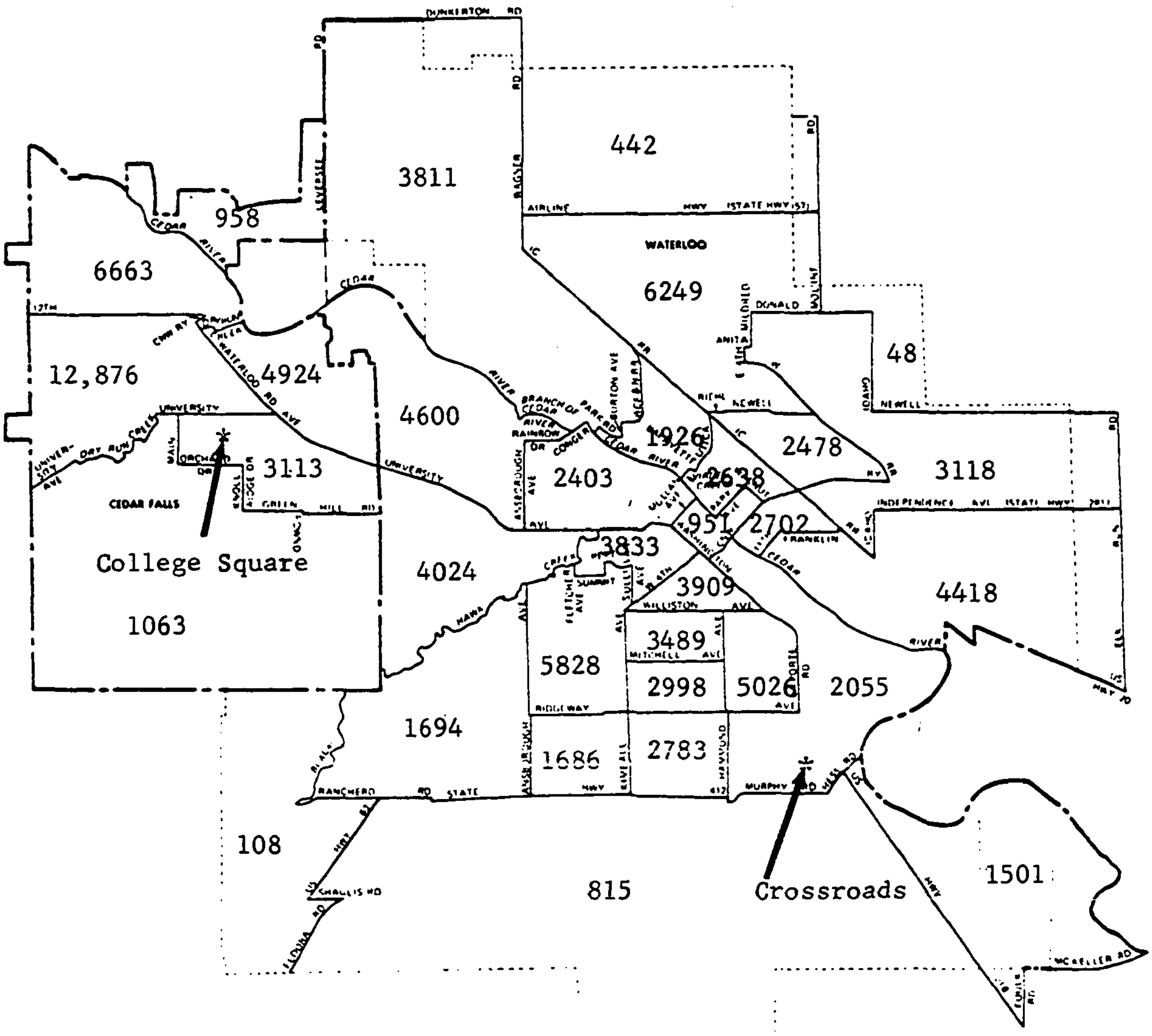


Figure 3. Waterloo metropolitan area street and highway network



Cedar Falls total = 29,597
Evansdale total = 6,066
Waterloo total = 75,533

Figure 4. Population distribution according to the 1970 census

displays, and frequent staged events provide an attractive atmosphere. Parking spaces are provided for approximately 3500 autos in a landscaped lot. Internal circulation driveways and parking access aisles are clearly identifiable and designed to reduce conflicts with pedestrians and other autos. Figure 5 is a site plan of College Square.

Crossroads Shopping Center

The Crossroads shopping center was constructed in 1969 by Crossroads of Minneapolis. As noted in Figure 3, it is located on US 218 in the southeast part of Waterloo. Access to US 218 and to Iowa 412 assures crosstown travel times of less than 20 minutes. The future freeway Iowa 520 will be located adjacent to the center, reducing travel times for some metropolitan area shoppers.

The site contains approximately 80 acres, with 723,000 square feet devoted to buildings. Fifty-four stores with more than 1400 employees offer merchandise and services through 525,000 square feet of retail sales area. The enclosed climate-conditioned mall provides a comfortable attractive atmosphere for shoppers. Stores are at two levels with escalators and stairs in the mall. The open two level mall has plants, furniture, displays and frequent staged activities which, in conjunction with the accumulation of retail selection, is one of the most attractive in Iowa.

As can be noted in Figure 4, residential concentrations have ready access to the center. An outer perimeter circulation roadway distributes

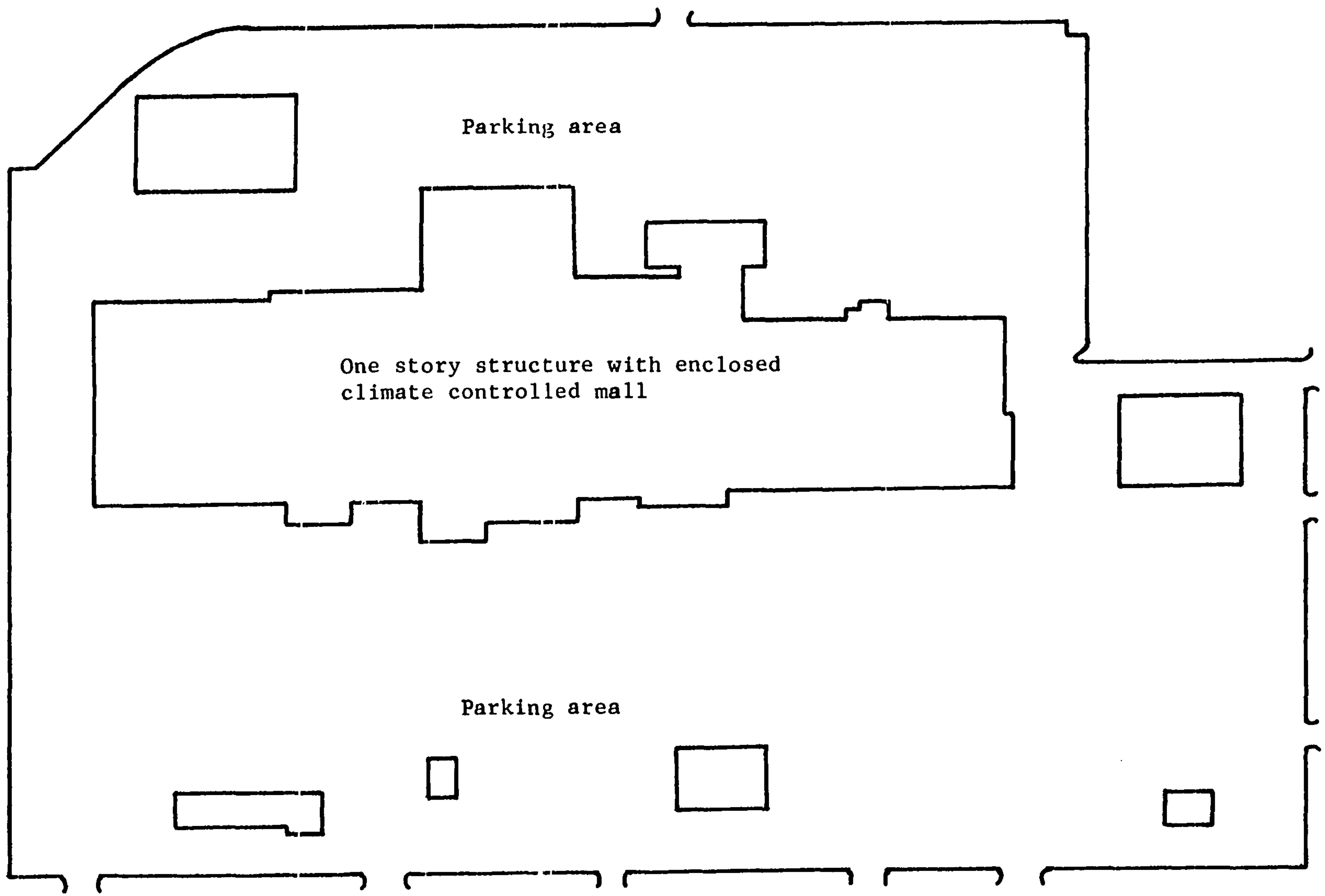


Figure 5. College Square shopping center site plan

the center's traffic to the upper or lower level parking areas. Total parking for approximately 5000 autos is available. Figure 6 is a site plan for Crossroads center.

License Plate Survey

The basic data for this study are the individual license plate numbers which were recorded at each shopping center's parking lot. These raw data were later translated into shopper's trips which were assigned to a specific census tract of the Waterloo-Cedar Falls-Evansdale area. Funding and staffing limitations precluded a continuous recording of all vehicle numbers during a day. Also, the multitude of entrances and the difficulty of noting the numbers on moving vehicles ruled out the recording of vehicles as they entered the center.

Following a discussion with the graduate committee relative to sample size a preliminary investigation was conducted. The results indicated that one person could record approximately one half of the accumulated vehicle's license plates at a center in one hour. Thus, a staff of four persons could record both shopping centers for a given one hour period of time. It was also apparent that a rest period was necessary at the completion of a trip through the parking lot. Another factor of concern was the length of time the centers were open for business. Both centers were open from 10:00 a.m. to 9:00 p.m. on weekdays, from 10:00 a.m. to 6:00 p.m. on Saturday, and from 12:00 noon to 6:00 p.m. on Sunday.

Based on the staffing available and personal physical limitations

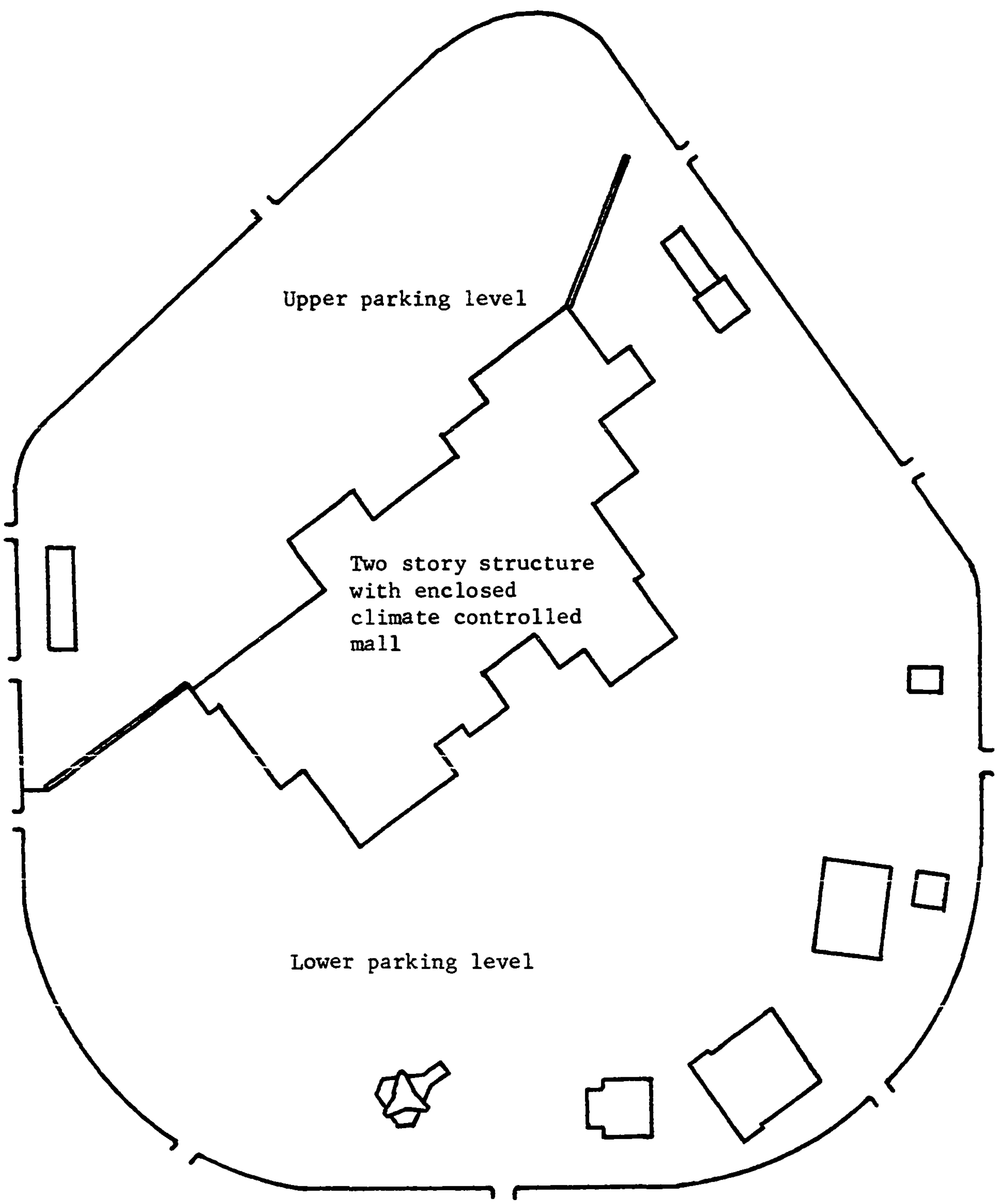


Figure 6. Crossroads shopping center site plan

the sample size was limited to one-hour surveys, conducted at three-hour intervals. Two persons at each center would simultaneously record all vehicles accumulated. Thus daily vehicle license plates were recorded in accordance with the following schedule: Weekdays at 10:00 a.m., 1:00 p.m., 4:00 p.m., and 7:00 p.m., Saturday at 10:00 a.m., 1:00 p.m., and 4:00 p.m., and Sunday at 1:00 p.m. and 4:00 p.m. Seven days of data recording were accomplished, one for each day of the week, over a period of three weeks from July 24, 1972 through August 16, 1972.

A tally sheet form was devised to simplify and standardize the data recording. A portion of the page was designated Black Hawk County, thus requiring the recording of only the individual (noncounty) numbers. Another portion of the sheet was designated for "other" Iowa counties requiring the full field of numbers to be recorded. Out of state vehicles were identified simply by the state. As no recording trips were scheduled on successive days the interval allowed a summarization of the data previously gathered.

No particular difficulties were encountered, no rainfall occurred, and the schedule was maintained as planned. Quite frequently the vehicle's operator was curious and questions were asked. In two cases individuals were concerned and demanded the removal of the recorded number. They felt this activity was an infringement on their personal rights.

During the approximately two hours available between recording sessions the shopping center characteristics were investigated. Individual store characteristics were obtained which were later aggregated and used to measure the attractiveness factor of each center. The cooperation of the center managers and the store operators was excellent.

Travel Times

A significant factor for an individual in selecting a shopping destination is the spatial separation of the home and the destination. Distance can be a measure of this impedance factor and is readily obtained from a map. As will be discussed later, travel time is considered a more significant measure of the individual's propensity to travel.

The Iowa State Highway Commission has completed a transportation plan for this metropolitan area. A traffic assignment map and a network skim (time) table was obtained from the Urban Department. The transportation zones were not the same as the census tracts, but were generally smaller and could be utilized. The approximate centroid of the census tract was first identified. Then the nearest transportation zone centroid was located and the travel time difference noted. A travel time table, see Table 3, was readily developed.

Table 6. Travel time (d_{ij})

Census tract (i)	Travel time (in minutes) College Square j = 1	Crossroads j = 2
1	11	6
2	12	7
3	10	7
4	6	9
5	11	11
6	11	8
7	14	6
8	16	6
9	14	2
10	13	3
11	12	5
12	13	3
13.01	14	3
13.02	14	6
14	10	7
15.01	9	5
15.02	7	13
15.03	6	13
16	11	14
17	13	10
18	14	9
19	14	5
20	22	13
21	8	19
22	7	20
23	6	19
24	4	15
25	3	14
26.01	4	15
26.02	13	14
27	18	11
29.01	15	2
30.01	11	5
30.02	9	9

DATA ANALYSIS

Summary of Raw Data

At the completion of the field survey phase the tally sheets were summarized. Some very interesting consistencies were apparent from the 40,898 vehicles processed. The results are presented in Tables 4 and 5. Out-of-state vehicles for example, were never less than two percent or more than five percent of the individual hourly recorded vehicles. Also, only three of the 50 states were not represented. Surprisingly Hawaii and Alaska plates were recorded. Approximately 25 percent of the hourly recordings were "other" Iowa counties. The highest percentage of other than Black Hawk county vehicles recorded occurred on Sunday at both centers. Distributions of vehicles recorded from other Iowa counties are tabulated in Figures 7 and 8. As would be expected adjacent counties have the highest volumes.

An unexpected distribution of larger than minimal volumes appears across the state to the west for the College Square center. One can theorize that this is due to the College Square location on US 20 and being readily visible to the cross state traveler.

The geographical distribution of out-of-state vehicles is presented in Figure 9. These vehicles consistently constituted three percent of the week's recorded volume and are probably not significant from a merchandising standpoint. These data are not a part of the final modeling analysis in this report, and are presented simply to present an overview of the total origin of vehicles.

Table 4. College Square Center - summary of all vehicles recorded

Day	Time of count	Black Hawk County	Per-cent	Other Iowa counties	Per-cent	Out of state	Per-cent	Total vehicles parked	Per-cent
Monday (7/24/72)	10:00	347	77	92	20	14	3	453	21
	1:00	420	70	158	26	25	4	603	27
	4:00	382	71	137	26	18	3	537	24
	7:00	426	70	162	27	21	3	609	28
Daily total		1575	72	549	25	78	3	2202	13
Tuesday (8/8/72)	10:00	307	73	102	25	9	2	418	14
	1:00	573	66	255	29	40	5	868	30
	4:00	508	66	228	30	33	4	769	26
	7:00	603	70	225	26	39	4	867	30
Daily total		1991	68	810	28	121	4	2922	17
Wednesday (8/16/72)	10:00	313	82	57	15	13	3	383	14
	1:00	529	68	217	28	33	4	779	29
	4:00	472	68	199	28	28	4	699	26
	7:00	602	73	196	24	28	3	826	31
Daily total		1916	71	669	25	102	4	2687	16

Table 4. (continued)

Day	Time of count	Black Hawk County	Per-cent	Other Iowa counties	Per-cent	Out of state	Per-cent	Total vehicles parked	Per-cent
Thursday (8/10/72)	10:00	431	72	140	23	29	5	600	21
	1:00	507	67	223	29	28	4	758	26
	4:00	497	67	218	29	29	4	744	25
	7:00	599	72	204	25	26	3	829	28
Daily total		2034	69	785	27	112	4	2931	17
Friday (7/28/72)	10:00	295	81	64	17	6	2	365	14
	1:00	480	72	162	24	25	4	667	27
	4:00	454	70	174	27	19	3	647	26
	7:00	582	70	209	25	42	5	833	33
Daily total		1811	72	609	24	92	4	2512	15
Saturday (8/12/72)	10:00	295	71	105	25	16	4	416	20
	1:00	603	71	224	26	23	3	850	40
	4:00	591	70	223	26	31	4	845	40
Daily total		1489	71	552	26	70	3	2111	13

Table 4. (continued)

Day	Time of count	Black Hawk County	Per-cent	Other Iowa counties	Per-cent	Out of state	Per-cent	Total vehicles parked	Per-cent
Sunday (7/30/72)	1:00	524	67	233	30	20	3	777	50
	4:00	472	61	281	37	16	2	769	50
Daily total		996	64	514	33	36	3	1546	9
Week total									
	10:00	1988		560		87		2635	16
	1:00	3636		1472		194		5302	31
	4:00	3376		1460		174		5010	30
	7:00	2812		996		156		3964	23
Total		11,812	70	4488	27	611	3	16,911	

Table 5. Crossroads Center - summary of all vehicles recorded

Day	Time of count	Black Hawk County	Per-cent	Other Iowa counties	Per-cent	Out of state	Per-cent	Total vehicles parked	Per-cent
Monday (7/24/72)	10:00	505	83	94	15	13	2	612	19
	1:00	687	75	207	22	26	3	920	28
	4:00	596	74	192	24	20	2	808	24
	7:00	732	76	208	22	26	2	966	29
Daily total		2520	76	701	21	85	3	3306	14
Tuesday (8/8/72)	10:00	560	79	118	17	26	4	704	18
	1:00	832	72	291	25	40	3	1163	30
	4:00	700	71	259	26	30	3	989	26
	7:00	733	74	215	22	36	4	984	26
Daily total		2825	74	883	23	132	3	3840	16
Wednesday (8/16/72)	10:00	622	79	146	19	19	2	787	21
	1:00	747	71	263	25	45	4	1055	29
	4:00	657	74	194	22	36	4	887	24
	7:00	698	75	212	23	26	3	936	26
Daily total		2724	74	815	22	126	3	3665	15

Table 5. (continued)

Day	Time of count	Black Hawk County	Percent	Other Iowa counties	Percent	Out of state	Percent	Total vehicles parked	Percent
Thursday (8/10/72)	10:00	659	79	159	19	16	2	834	21
	1:00	864	73	291	24	36	3	1191	30
	4:00	714	74	214	22	37	4	965	24
	7:00	777	76	220	22	23	2	1020	25
Daily total		3014	75	884	22	112	3	4010	17
Friday (7/28/72)	10:00	565	82	112	16	19	3	696	18
	1:00	858	77	221	20	29	3	1108	28
	4:00	837	79	187	18	29	3	1053	27
	7:00	862	78	211	19	32	3	1105	28
Daily total		3122	79	731	18	109	3	3962	16
Saturday (8/12/72)	10:00	664	80	153	18	12	2	829	25
	1:00	1025	75	305	22	38	3	1368	41
	4:00	836	75	258	23	28	2	1122	34
Daily total		2525	76	716	22	78	2	3319	14

Table 5. (continued)

Day	Time of count	Black Hawk County	Per-cent	Other Iowa counties	Per-cent	Out of state	Per-cent	Total vehicles parked	Per-cent
Sunday (7/30/72)	1:00	652	66	313	32	28	3	993	53
	4:00	583	65	283	32	26	3	892	47
Daily total		1235	65	596	32	54	3	1885	8
Week total									
	10:00	3575		782		105		4462	19
	1:00	5665		1891		242		7798	32
	4:00	4923		1587		206		6716	28
	7:00	3802		1066		143		5011	21
Total		17,965	75	5326	22	696	3	23,987	

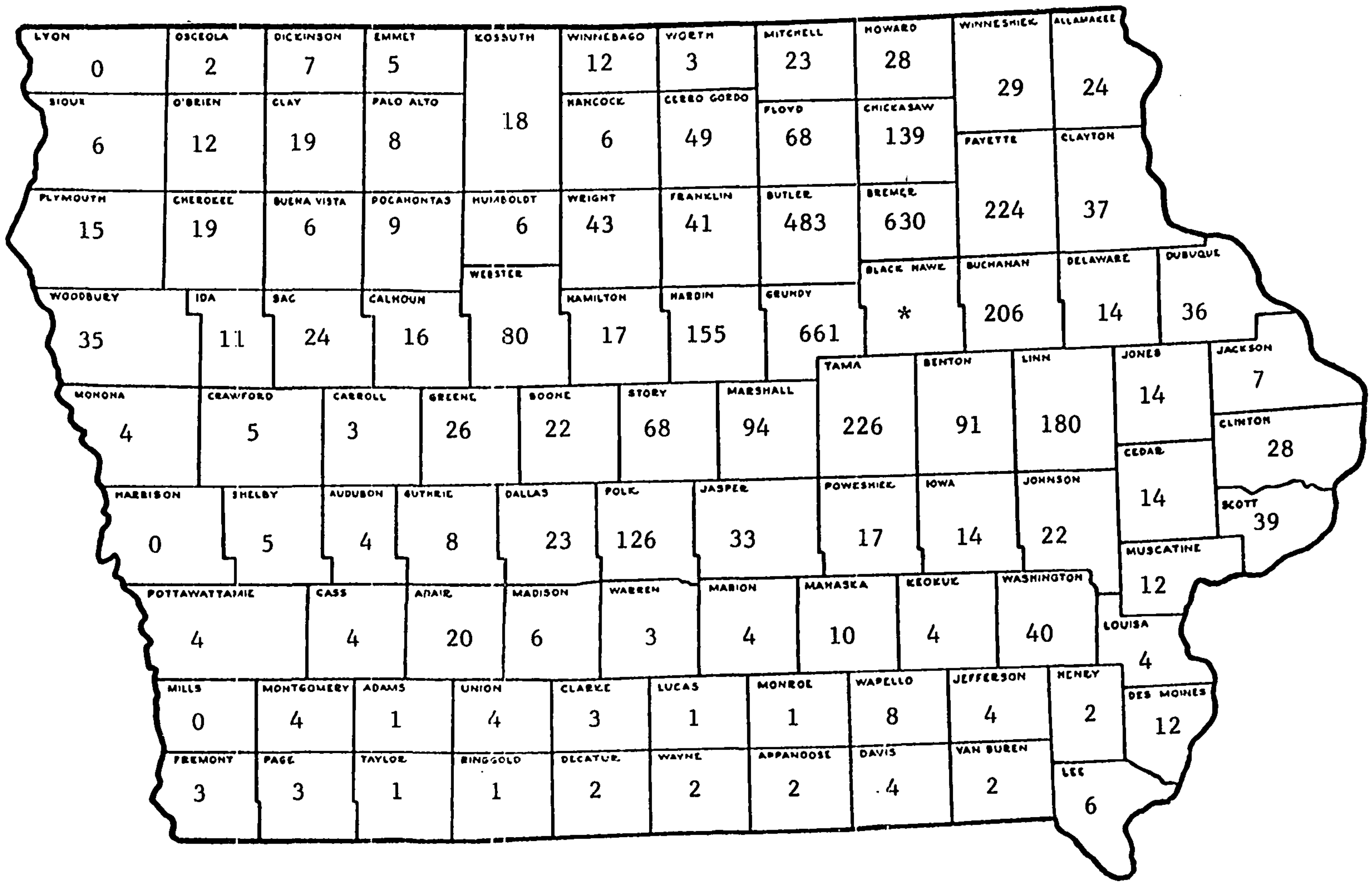


Figure 7. College Square shopping center, parking lot survey, weekly total of other Iowa counties. Total 4476 vehicles

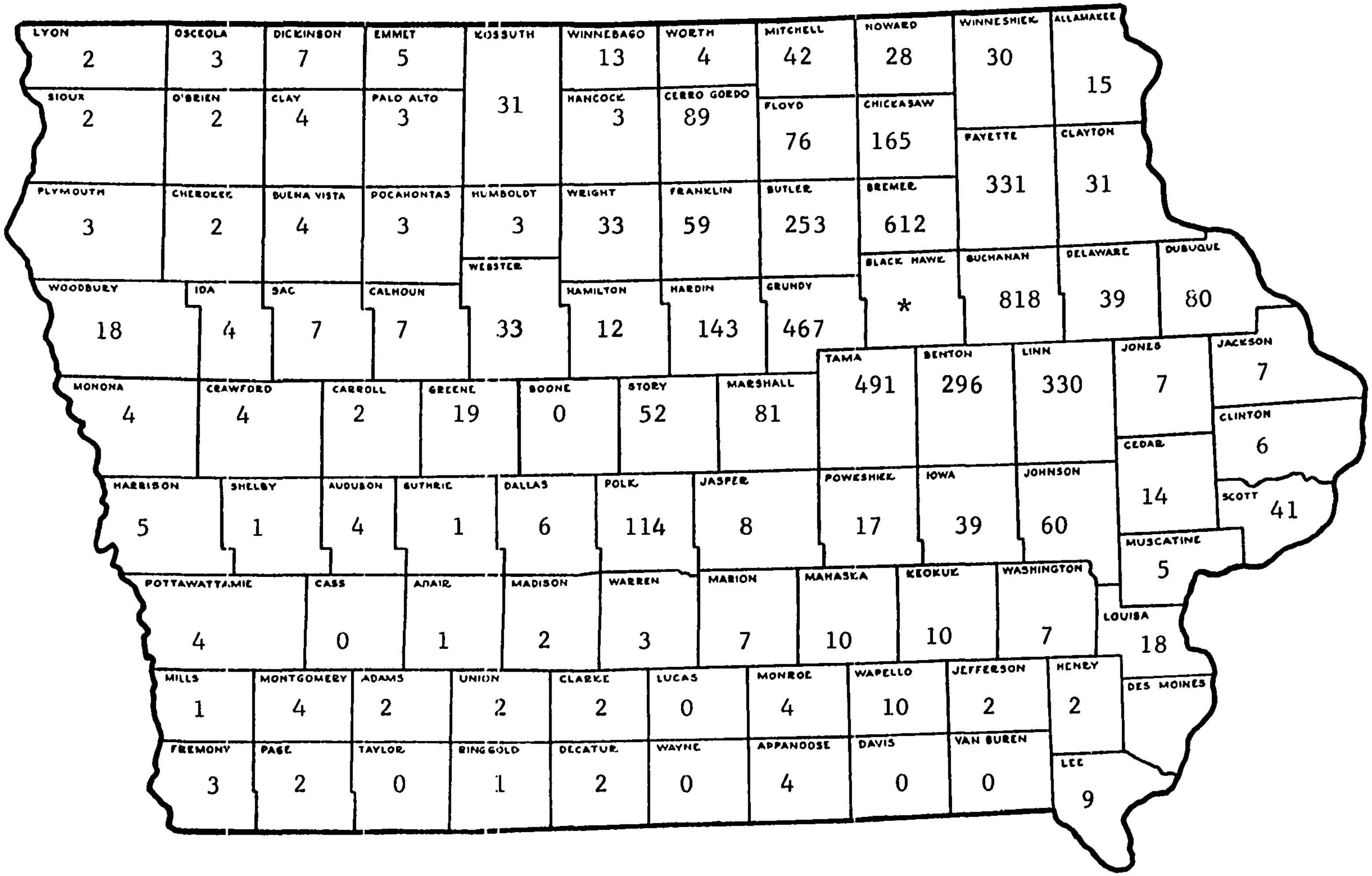
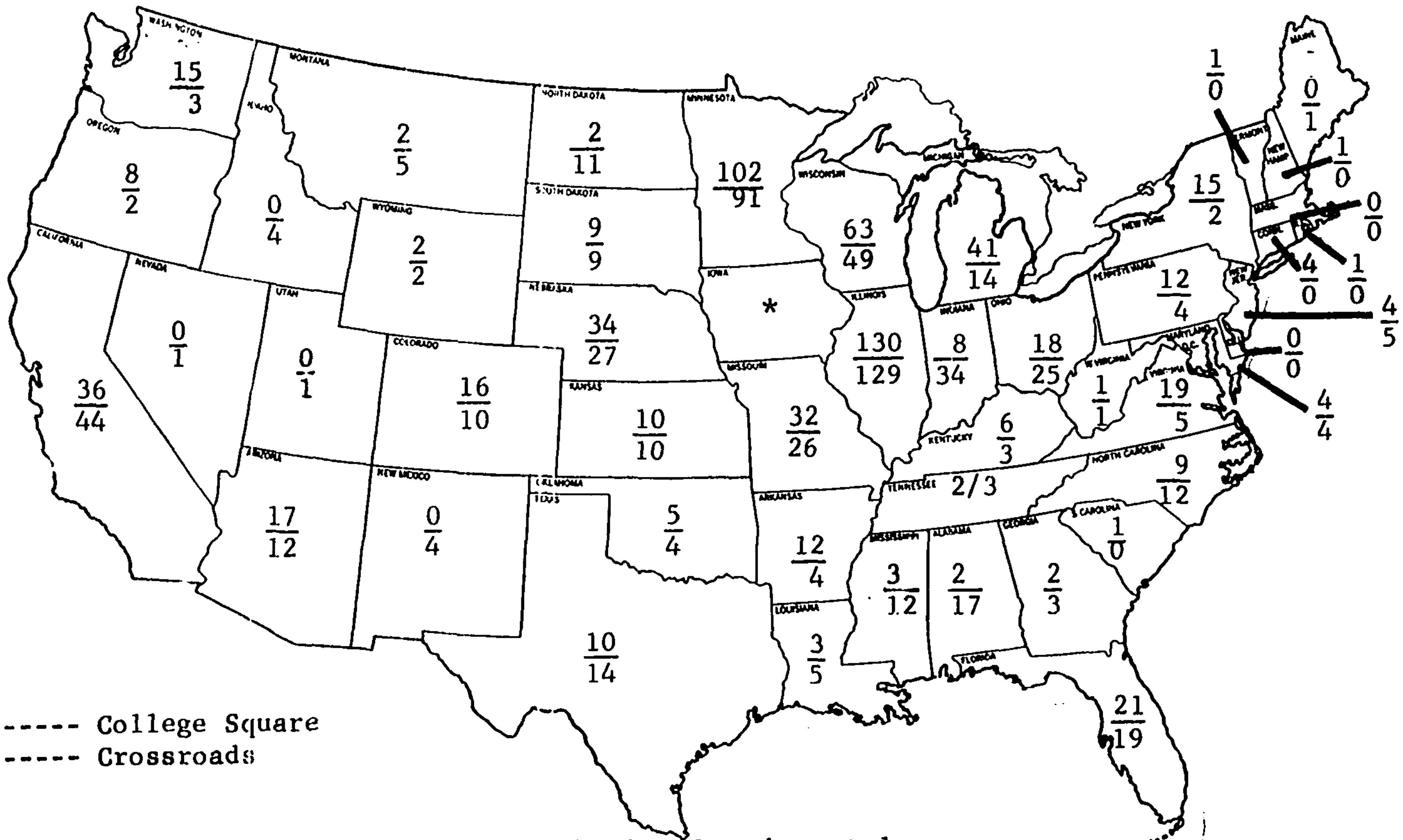


Figure 8. Crossroads shopping center, parking lot survey, weekly total of other Iowa counties. Total 5307 vehicles



102 ----- College Square
91 ----- Crossroads

Figure 9. Distribution of out-of-state vehicles for the total survey

Identification of Shoppers

The initial step in processing the raw data was to punch each recorded Black Hawk County vehicle's license plate number on a data processing card. The format included the shopping center code number, the month, day, and hour, and the plate number. Upwards of 29,000 Black Hawk County vehicles were subsequently translated to punched card format.

During the data gathering phase an effort was made to identify employee's vehicles. It was noted that certain areas in the parking lots were reserved for employees. However, it was soon apparent that an occasional shopper used the employee's area, and a large number of employees were distributed throughout the lots. In an attempt to provide aid, the shopping center store managers circulated a form letter requesting their employees to participate in the study by providing their license numbers. A few were obtained in this manner but suspicion of the managers request was apparent. Employees did not want the manager to know where they were parked in many cases.

A method of identifying employees, to supplement the voluntary list, had to be devised. The method selected was to delete any vehicle recorded on any five days at a center. The deletions were considered employees. Obviously this arbitrary proposal introduces error, but the errors tend to cancel to some degree. For example, a persistent shopper might logically visit a center on five days during the study period. Also, an employee might use a different vehicle on one work day, thus disqualifying him as an employee.

In order to identify and remove employee's cards the 29,777 Black Hawk County punched cards were first machine sorted into ascending license plate order. Each card was then interpreted by hand with the employee's cards being removed. The approximately 21,000 cards remaining represented shopper vehicles. However, in many cases the same shopper's vehicle was recorded at successive hours during a day. At a later stage vehicles recorded more than one time during one day were considered as one trip. The resulting cards were then considered to represent shopping trips.

Shoppers' Origin Identification

Identification of a shopper's residence from a recorded license plate number was accomplished by utilizing motor vehicle registration lists for Black Hawk County. Originally it had been anticipated that the actual translation of a recorded vehicle number to an address could be accomplished in the county treasurer's office. However, the large number of vehicles recorded during the study would have required an inordinate amount of time. A listing of Black Hawk County motor vehicle numbers with corresponding addresses was subsequently obtained from the local credit bureau. This action significantly reduced the time for the address location identification phase of the study.

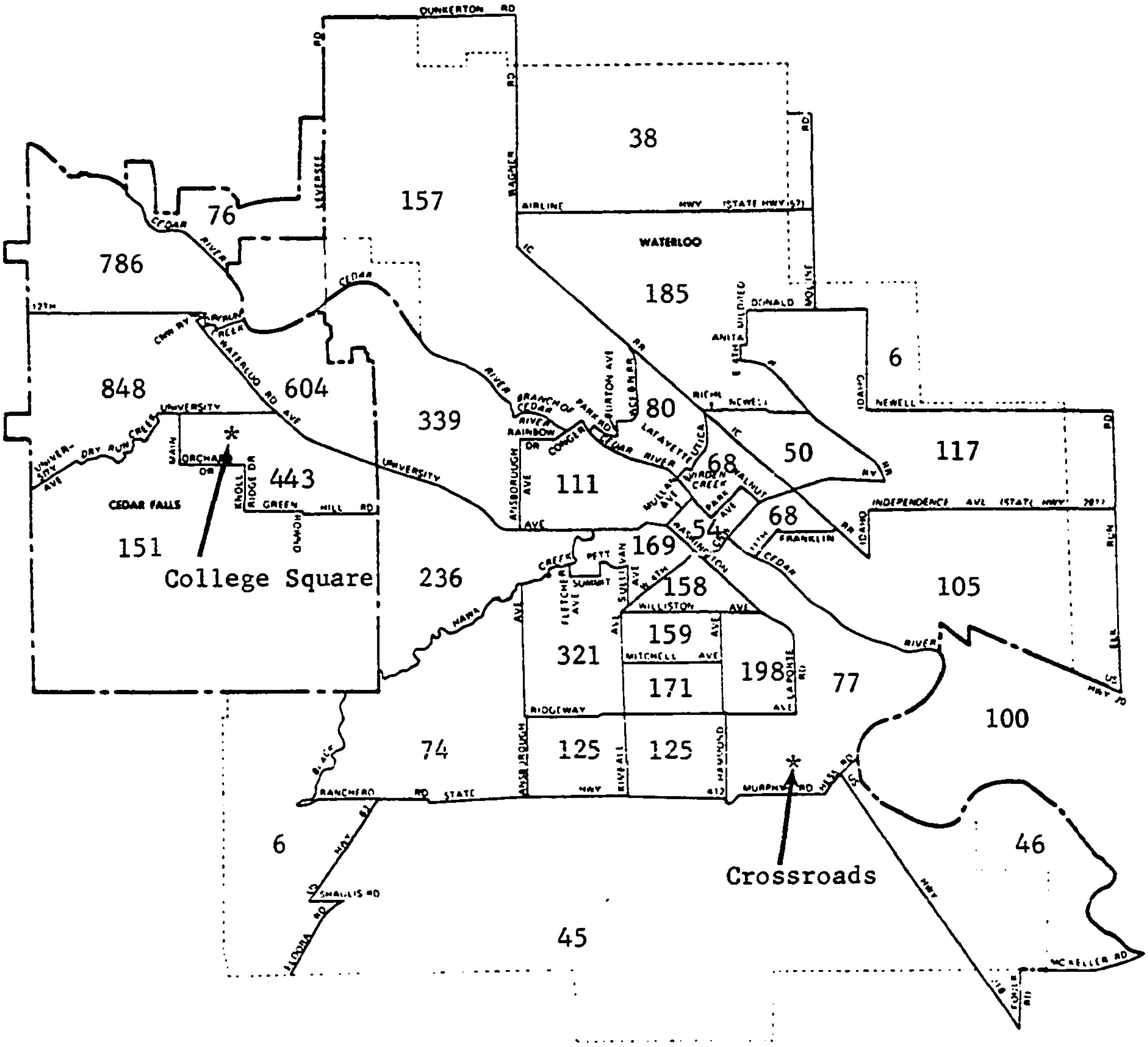
The Metropolitan Planning Commission of Black Hawk County provided base maps for Waterloo, Cedar Falls, and Evansdale. A street address index code was obtained for each city to facilitate the process of locating an address. Census tracts were superimposed on the street address base maps.

Next it was necessary to: 1) select the license plate number from the punched card, 2) look up the street address in the county treasurer's listing, 3) locate the address on the base map, 4) identify the census tract number for that location, and 5) record the census tract number on the card. When all 21,000 cards had been processed they were sorted by hand into sets of census tracts. The census tract number was then punched on each card.

The final step involved a machine sorting to array the cards in increasing license plate number, by shopping center, and by census tracts. Duplication of vehicles recorded on any one day were removed and the resulting 17,896 cards were summarized as shopper trips sorted by census tract, by day, and by shopping center.

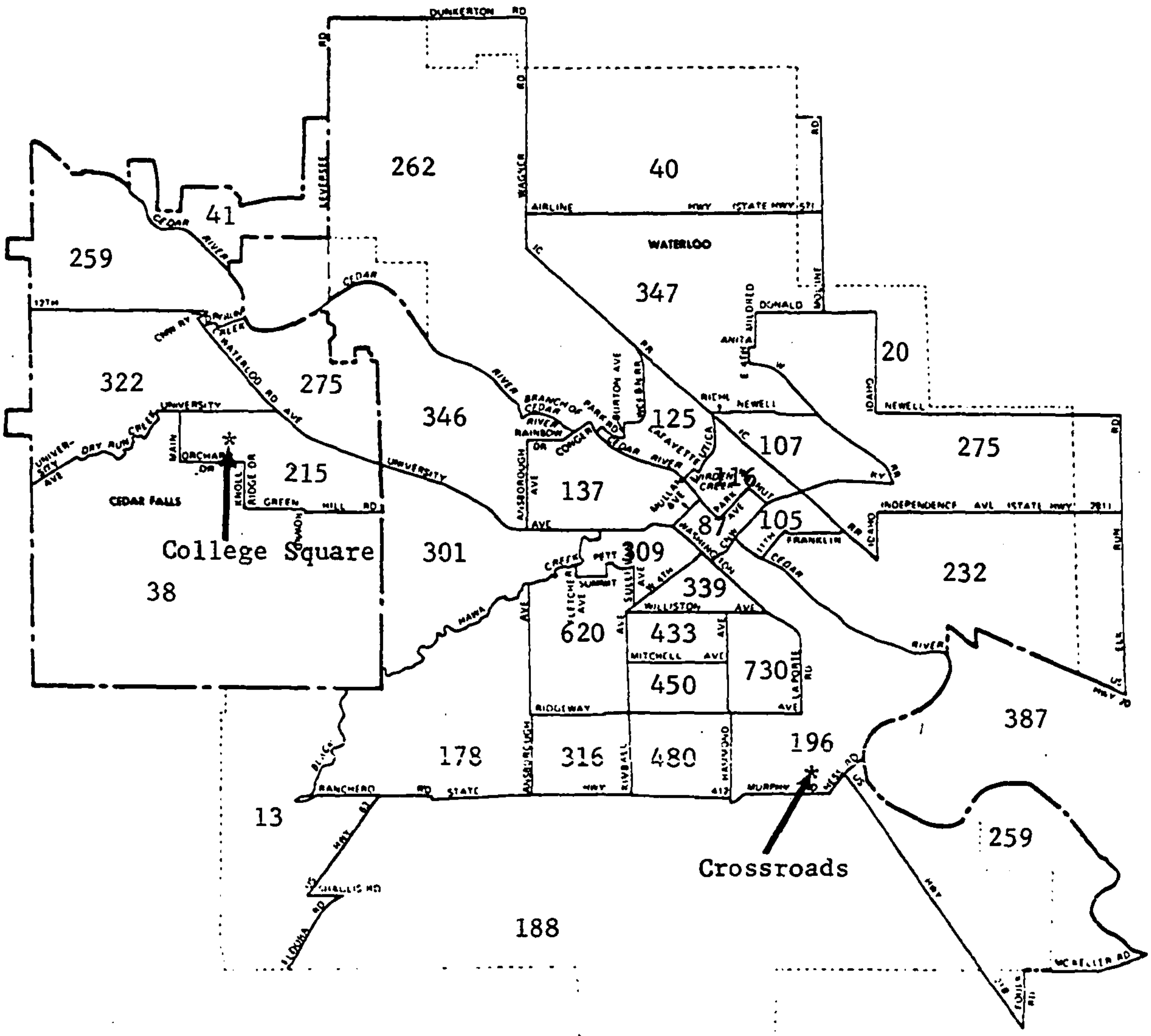
Figures 10 and 11 graphically illustrate the distribution of the total week's aggregated shopper trips within the Waterloo-Cedar Falls areas. Table 6 tabulates the same trips in the rural areas. Rural shopping trips were not utilized in the final modeling due to the overlapping census tract feature.

Table 7 is the final tabular summation of recorded shopper trips by census tracts. These data are the dependent variable for a shopper behavioral model.



Cedar Falls total = 2908
Waterloo total = 3288

Figure 10. Total recorded shopping trips, by census tract, at College Square



Cedar Falls total = 1150
Waterloo total = 7011

Figure 11. Total recorded shopping trips, by census tract, at Crossroads

Table 6. Total recorded shopping trips by Black Hawk County postal address/census tract outside of Waterloo-Cedar Falls

Postal address	Census tract[a]	Shopping trips College Square	Shopping trips Crossroads
Waterloo RR#1	30.02	138	61
#2	26.02	25	54
#3	27.00	24	46
#4	30.02	24	101
#5	27.00	28	60
Cedar Falls RR#1	26.02	81	91
#2	30.02	40	34
#3	26.02	71	30
#4	26.02	40	14
#5	22.00	41	19
Dunkerton	28.00	44	79
Janesville	26.02	29	12
Evansdale	20.00	100	387
Hudson	30.02	102	231
Washburn	29.02	41	250
Gilbertville	27.00	13	78
Raymond	27.00	12	64
Jesup	28.00	19	73
Dewar	27.00	11	17
Elk Run Heights	20.00	11	17
La Porte City	29.02	72	366
Total		966	2086

[a]Census tracts usually cover more than one postal area.

Table 7. Trip Interchanges (T_{ij})

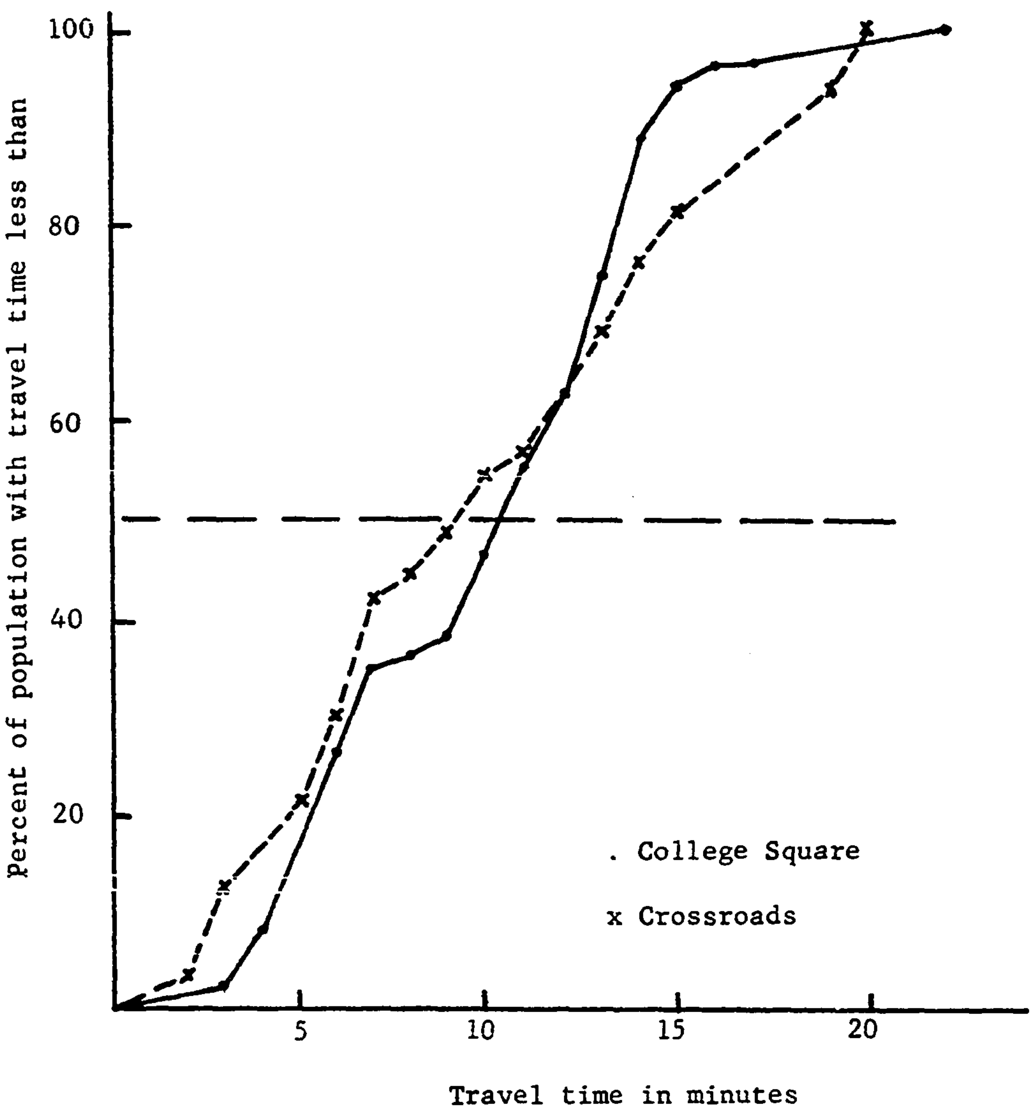
Census tract (i)	Trip Interchange	
	College Square j = 1	Crossroads j = 2
1	54	87
2	158	339
3	169	309
4	111	137
5	80	125
6	68	116
7	68	105
8	105	232
9	77	196
10	198	730
11	159	433
12	171	450
13.01	125	480
13.02	125	316
14	321	620
15.01	74	178
15.02	236	301
15.03	339	346
16	157	262
17	185	347
18	50	107
19	117	275
20	100	387
21	76	41
22	786	259
23	848	322
24	604	275
25	443	215
26.01	151	38
26.02	38	40
27	6	20
29.01	46	259
30.01	45	188
30.02	6	13
Total 34	6,296	8,548
Total = 14,844		

Travel Time Analysis

It was noted in the literature that Brunner and Mason (12) had studied travel times to Toledo, Ohio shopping centers. Certain characteristics of Toledo shoppers' driving times were recorded in Table 7. In order to evaluate the travel times obtained for the Waterloo centers, cummulative driving time distributions from each census tract to each center were prepared.

Figure 12 is included to compare the two Waterloo shopping center travel times to the Toledo data. It is apparent that Waterloo shopping center primary trade area travel times are somewhat less than Toledo, Ohio. This probably is due in a large part to the smaller size of the Waterloo area, and the resultant reduced congestion and ease of driving.

A number of studies reviewed in the literature search phase noted the variation in travel time exponents. These variations are a function of trip purpose and differentiation occurs between shopper goods trips and convenience goods. From observation of Figure 12 it is apparent that the travel time factor is less restrictive in Waterloo than in a larger more congested area.



Shopping center	Cumulative driving time in minutes 0-5	0-10	0-15	0-20
College Square	17%	46%	95%	98%
Crossroads	21%	54%	82%	100%

Figure 12. Cumulative travel time distributions to competing Waterloo shopping centers based on data from Table 3

AN EMPIRICAL MODEL FOR PREDICTING TRAVEL TO COMPETING SHOPPING CENTERS

Identification of Variables

As a result of the literature review a basic concept of model form and content developed. The goal of this research was to develop a model that would replicate shopper trips to competing shopping centers. The data were obtained from the license plate survey, as refined to include only shoppers, and presented in Table 4. The independent variables representing propensity of an area to produce trips were obtained from census publications. Those characteristics of the population considered suitable for further model analysis have been tabulated in Table 2. Travel time data from each census tract to each center have been presented in Table 3. The characteristics of the shopping centers were obtained during the field survey and are evaluated later in the thesis.

These components have consequently been identified for consideration in the model form:

$$T = f(P,Z,d)$$

where:

T = shoppers trips

P = trip production characteristics of an area

Z = shopping center trip attraction characteristics

d = a measure of spatial separation.

The production of a trip from home to shop obviously infers certain conditions. People with money and with transportation must be available. Thus, population, average income, and multiple cars per household might be measures of the propensity of an area to produce shopper trips. However, these variables are inter-related to some degree and may require modification. In the literature search it was apparent that market analysts depend heavily on population density and various measures of disposable income in shopping center location studies. Thus, these are prime independent variable candidates.

An investigation of the 1970 Census report indicated a number of social-economic variables considered suitable for detailed analysis. These are characteristics of the population that to some degree measure the propensity of an area to produce shopper trips. Note that these are readily available data identified at the census tract level. Table 2 tabulates the value for each variable by census tract (i).

X_1 = population

X_2 = median income in dollars

X_3 = renter/owner housing ratio

X_4 = nonworker/worker ratio

X_5 = percent Negro

X_6 = median home value in thousands of dollars

X_7 = percent of poverty income families

X_8 = percent of college educated persons

X_9 = persons per household

X_{10} = percent persons in a different house five years ago

X_{11} = autos per household.

Shopping center characteristics are frequently difficult to obtain. Information relative to sales for example are closely guarded in most cases. Sales tax information can not be obtained (except in grossly aggregate form) from a governmental agency. The following list of characteristics represent potential trip attraction factors:

1. total land area
2. total building floor area
3. total retail sales area
4. shopper goods retail sales area
5. consumer goods retail sales area
6. number of employees
7. number of stores
8. amenities
9. merchandising expertise
10. sales volume.

Table 8 tabulates values for those attractiveness factors readily available in this study. Obviously many mathematical combinations utilizing these variable exist. For example, it could be rationalized that retail sales area represents size, which becaause of the investment has a high probability that good merchandising practices exist. However, the number of employees might also be considered as an appropriate measure of the level of service; and the number of stores the degree of variety. Thus, one might hypothesize that an equation of the following form should be tested:

Table 8. Shopping center characteristics

College Square j = 1	
Number of employees	769
Retail space	388,111 sq. ft.
Total space	470,823 sq. ft.
Number of stores	56
Approximate No. parking spaces	3500
Crossroads j = 2	
Number of employees	1,432
Retail space	524,263 sq. ft.
Total space	723,024 sq. ft.
Number of stores	54
Approximate No. parking spaces	5000

$$Z = f(RSA^x, E, S)$$

where:

Z = shopping center attractiveness factor

RSA = retail sales area in 100,000 square feet

E = total number of employees

S = total number of stores

X = an exponent.

A multitude of potential equations could in fact be developed just for this particular component. For the initial model development the following variable was selected as constituting the most fundamental measurement of shopping center attractiveness. Most other variables to some degree are correlated with this variable.

$$Z = \frac{\text{Retail sales area in sq. ft.}}{100{,}000} \ .$$

At a later stage, during the model testing and analysis, additional variables were tested in an attempt to improve the model.

As was noted in a number of studies in the literature, the spatial separation function, which measures the impedence to travel, has received extensive research evaluation. The travel time factors and friction factors used in transportation planning models are quite sophisticated. Three principles can be stated as representing current practice based on logic and empirical studies. First, distance is not the best measure of spatial separation effect. Variations in route, level of development, the density of traffic flow, accident potential situations, and congested locations are examples of why distance alone is misleading. Travel time however is accepted as taking into account these variations and providing the most meaningful variable.

A second principal that has been established, and has been discussed previously, places the travel time factor in the denominator. Travel time is inversely related to the propensity to shop. People obviously will select the shorter trip to satisfy a particular need. A third principle states that an exponent must be used for the travel time variable. Also, the exponent is determined from empirical studies and varies according to trip length and trip purpose. The initial variable form selected as representing travel time impedence, has the following terms:

$$\frac{k}{d_{ij}^{x}}$$

where:

d_{ij} = travel time from census tract i to center j

x = an empirically developed exponent

k = a constant.

Formulation of a Model

The three components previously noted as best representing shopper trip variables can be closely related to the gravity model concept. That is:

$$T_{ij} = P_i \frac{Z_j}{d_{ij}^{x}}$$

where:

T_{ij} = shopper trips from census tract i to center j

P_i = a measure of the trip production ability of census tract i

Z_j = the attractiveness of center j

d_{ij} = the travel time from census tract i to center j

x = an exponent to be determined from study data

i = census tract numbers (1-34)

j = shopping center number (1-2).

The ground work has been laid previously for acceptance of a model of this form. It does not deviate from current accepted practice. A deviation does occur to some extent however when the term P_i is replaced by the variables representing the population characteristics that measure the propensity to produce shopper trips.

$$T_{ij} = (\beta_0 + \beta_1 X_{1i} + \ldots\ldots \beta_n X_{ni}) \frac{Z_j}{d_{ij}^{\,x}}$$

where:

β_n = coefficients to be determined from linear regression analysis

X_{ni} = social economic characteristics of census tract i as previously tabulated.

The next step in formulating the model is to develop an initial value for the exponent x. Later, through an iterative process, the exponent value may be refined. One can hypothesize that the travel time exponent may be approximated initially by eliminating many of the variables being considered. In fact the population of a census tract may be considered a single simple estimator. Thus an equation of the following form, utilizing known measured values of trips, population and travel time, was used.

$$T_{ij} = k \frac{P_i}{d_{ij}^{\,x}}$$

or,

$$\frac{T_{ij}}{P_i} = \frac{k}{d_{ij}^{\,x}}$$

and,
$$\log \frac{T_{ij}}{P_i} = \log k - X \log d_{ij}.$$

A plot of the values $\frac{T_{ij}}{P_i}$ versus d_{ij} is included as Figure 13. Scatter is apparent but a definite pattern exists.

The solution of the above equation, utilizing the measured data previously presented, yielded an x value = 0.7661. This value was incorporated in the model for the initial analysis. The value of k calculated, 0.4861 in this case, need not be used in the analysis, as the computer program will solve for the β values which will include constants.

A computer program for solving multiple linear regression equations was made available by the Iowa State University Statistical Laboratory. This program utilizes a backward elimination procedure, a forward selection, and a stepwise procedure in developing a model. In order to utilize the linear regression equation the basic equation was transformed as follows:

$$S = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots \beta_n X_{ni}$$

where:

$$S = \frac{T_{ij} \; d_{ij}^{\;0.7661}}{Z_j}$$

Statistical Evaluation

The coefficient of determination (r^2) is a measure of the total variance in the dependent variable which is "explained" by the independent

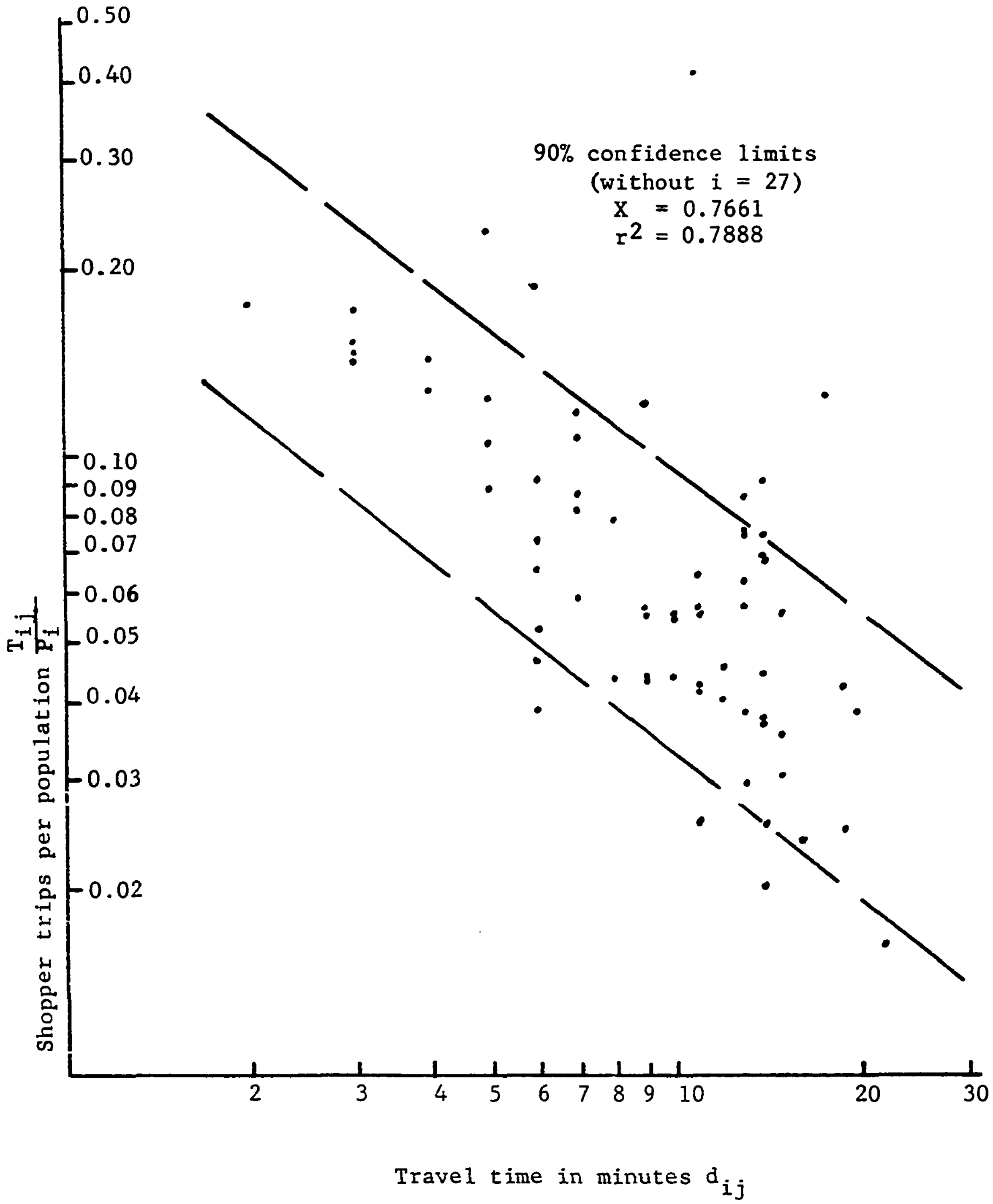


Figure 13. Trip interchanges per person versus travel times from all census tracts to both centers

variables. Various combinations of independent variables are selected and tested, with the higher (r^2) value generally indicating the better model.

$$r^2 = \frac{\sum_{u=1}^{n} (\hat{Y}_u - \bar{Y})^2}{\sum_{u=1}^{n} (Y_u - \bar{Y})^2}$$

where:

$(\hat{Y}_u - \bar{Y})^2$ = regression sum of squares, and is the deviation of the estimate from the mean due to regression, and is called the "explained" variation.

$(Y_u - \bar{Y})^2$ = a measure of the error resulting from using the mean, and is called the "total" variation.

The computer program uses a stepwise analysis to evaluate the changes occurring when independent variables are added or subtracted. The greatest reduction in the residual sum of squares is desired resulting in a higher (r^2) value. This procedure considers the associative relationship between independent variables and the dependent variable. However, independent variables may in fact have an effect by chance with no causal relationship apparent. Thus, the fact that a high (r^2) is achieved with a certain combination of independent variables does not necessarily mean the best combination exists. In the final choice of variables the logic of the relationship must be evaluated.

Figure 14 has been prepared to graphically summarize the three techniques employed to select the appropriate independent variables based on (r^2) value.

The correlation coefficient (r) is a measure of the degree of linear association between two variables. The presentation in the form

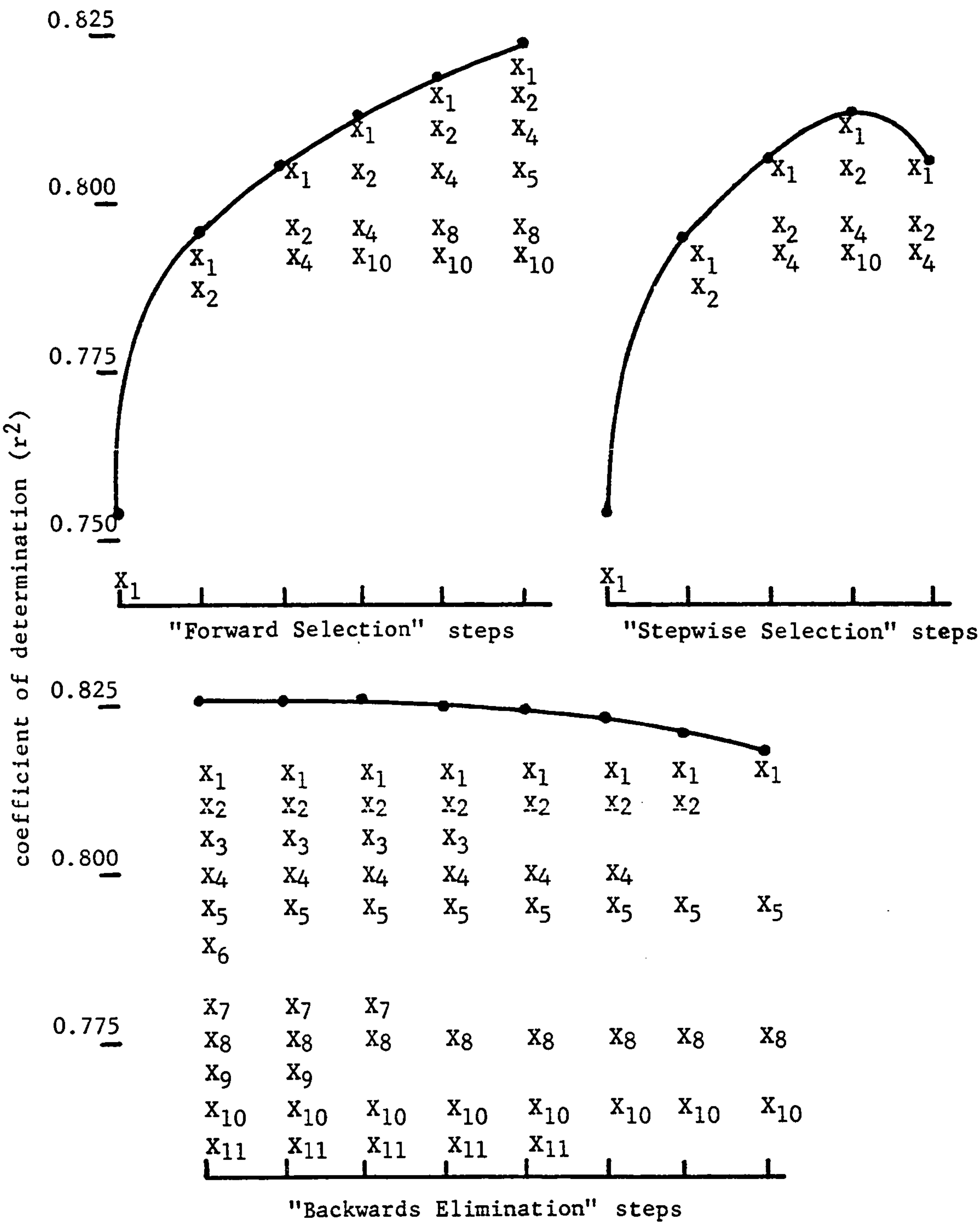


Figure 14. Stepwise computer analysis comparison. $(r)^2$ value for various combinations of independent variables (listed vertically at each step)

of a simple correlation matrix for all variables is useful for evaluating each variable for a logical and causative relationship. When a simple correlation matrix containing all variables is examined the existence of a high value between two variables indicates collinearity. These two variables in fact may measure the same characteristic and one is redundant when both are included in the same equation.

When the correlation between two independent variables is very high, and is higher than the correlation between each independent variable and the dependent variable, then collinearity is present. Examination of Table 9 for all independent variables tested indicates a number of cases of collinearity. A prime example is between the independent variables X_2 (income) and X_6 (home value). In the case of evaluating the high (r) for independent variables X_2 and X_6 it is logical that income (X_2) bears a causal relationship with shopping trips (Y) and should be in the equation. Home value (X_6) however, logically is a transformation of income (X_2) and is redundant when included in the same equation.

In the backward elimination computer program output the first independent variable dropped was X_6 (home value). In following succession the independent variables X_9 (persons per household), X_7 (percent poverty families), X_3 (renter/owner housing), and X_{11} (autos per household) were dropped. In the case of X_6, X_7, X_9, and X_{11} the correlation coefficient is high when compared to X_2 (income), is higher than X_2 and each other variable independently compared to S, and also

Table 9. Correlation coefficients - all variables

		X_1	X_2	X_3	X_4
Population	X_1	1.0000			
Income	X_2	-0.0351	1.0000		
$\frac{\text{Renter}}{\text{Owner}}$ housing	X_3	-0.1585	-0.4825	1.0000	
$\frac{\text{Nonworker}}{\text{Worker}}$	X_4	-0.1841	-0.3783	-0.0859	1.0000
Percent Negro	X_5	-0.0732	-0.3795	-0.0073	0.5222
Home value	X_6	-0.1267	0.8653	-0.1928	-0.2983
Percent poverty families	X_7	-0.1735	-0.7065	0.6341	0.4468
Percent college educated	X_8	0.2426	0.6554	-0.0957	-0.4664
Persons per household	X_9	-0.0585	0.5582	-0.6543	0.1822
Housing mobility	X_{10}	-0.2713	0.1776	0.1041	-0.0489
Autos per household	X_{11}	0.0908	0.8094	-0.5550	-0.4166
$S = \frac{T(D^{.7661})}{Z}$	S	0.8688	0.1720	-0.1600	-0.3338

X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	S
1.0000							
-0.3282	1.0000						
0.5261	-0.5083	1.0000					
-0.2745	0.6804	-0.4477	1.0000				
0.0217	0.4451	-0.5312	0.0960	1.0000			
-0.2319	0.3967	0.0030	0.1959	0.0196	1.0000		
-0.3951	0.6637	-0.8580	0.6035	0.6744	0.0683	1.0000	
-0.2133	0.0580	-0.3129	0.4011	-0.0178	-0.2722	0.2437	1.0000

logically X_6, X_7, X_9, and X_{11} can be considered as redundant measures of income.

The independent variable X_3 (renter/owner housing) however has a smaller value of (r) when compared to X_2 (income), but must be considered redundant on the same logic basis. On a logical basis it can be reasoned that the ratio of renters to owners is in fact an income characteristic.

A high degree of collinearity also exists between X_2 (income) and X_8 (percent college educated). It was however included in the forward selection and the backward elimination programs because it increased the r^2 value. On the surface, logic might suggest that the percent college educated actually is a measurement of income. One might however hypothesize that the propensity to shop (or brouse) in a modern shopping center is enhanced for persons with advanced education. If such were true the variable should be included even though collinearity is indicated.

Table 10 - A includes the variables remaining at this point: X_1, X_2, X_4, X_5, X_8, and X_{10}. It should also be noted that X_4 and X_5 have collinearity. Thus, if X_4 (nonworker/worker ratio) is excluded from the equation only independent variables X_1 (population), X_2 (income), X_5 (percent Negro), X_8 (percent college educated), and X_{10} (housing mobility) remain in the equation. The only significant collinearity exists between X_2 and X_8, and this effect has been rationalized in the previous discussion. Table 10 - B is the correlation coefficient matrix for the final model.

Table 10. Correlation coefficients - selected variables

A

	X_1	X_2	X_4	X_5	X_8	X_{10}	S
X_1	1.0000						
X_2	-0.0351	1.0000					
X_4	-0.1841	-0.3783	1.0000				
X_5	-0.0732	-0.3795	0.5222	1.0000			
X_8	0.2426	-0.6554	-0.4664	-0.2745	1.0000		
X_{10}	-0.2713	0.1776	-0.0489	-0.2319	0.1959	1.0000	
S	0.8688	0.1720	-0.3338	-0.2133	0.4011	-0.2722	1.0000

B

		X_1	X_2	X_5	X_8	X_{10}	S
Population	X_1	1.0000					
Income	X_2	-0.0351	1.0000				
Percent Negro	X_5	-0.0732	-0.3795	1.0000			
Percent college	X_8	0.2426	-0.6554	-0.2745	1.0000		
Housing mobility	X_{10}	-0.2713	0.1776	-0.2319	0.1959	1.0000	
	S	0.8688	0.1720	-0.2133	0.4011	-0.2722	1.0000

The t - test provides the opportunity to examine the probability that a regression coefficient (β) could have been obtained by chance when the real value was actually zero. As a step in the selection of the relative independent variables the probability for the hypothesis that $\beta = 0$ must be tested. Table 11 presents the final model values. Examination of the probability of $\beta = 0$ indicates less than 10 percent in all cases, except for X_2 (income). Or, we can be 90 percent confident that β is not equal to zero for the independent variables selected, except for X_2 (income).

Table 11. t - test for the hypothesis that $\beta = 0$

Source	β value	t-ratio	Probability $> \|t\|$
Intercept	38.1778	0.4888	0.6323
X_1	0.0720	13.2334	0.0001
X_2	0.0069	1.0726	0.2876
X_5	- 1.3918	- 1.8921	0.0599
X_8	3.4677	1.8066	0.0721
X_{10}	- 1.6250	- 2.1262	0.0352

After the independent variables to be retained in the final model had been selected the travel time exponent was reanalyzed. In the preliminary selection of the exponent, only population had been used to represent the trip production propensity. Having determined that five independent variables better represented this element, a number of values were tested for the travel time exponent in this revised model form. The (r^2) value was obtained for exponent values of 0.600, 0.766, 0.850, and 1.000. A plot of the (r^2) value versus the exponent value is shown in Figure 15. Note that the curve is relatively flat, indicating that a value from 0.75 to 1.00 would be suitable.

As was previously noted, the travel time exponents proposed in various studies are not always in agreement. Recommendations have varied from 0.5 to 3.0. As the travel time factor is in the denominator the higher values for the exponent would represent a higher impedance due to the distance. High exponent values would be correlated with a reduced secondary and tertiary trading area pulling power. The travel time exponent value of less than 1.0, arrived at in the Waterloo model iterative process, indicates that distance is not a significantly restrictive factor. Or, more simply stated, Waterloo center's primary trading area is extended a greater distance than might be found in a large congested metropolitan area, probably extending far into other center's trading areas, and with no clear cut boundaries.

The Z variable was based on the size of the shopping center sales area as a measure of its attractiveness. That is:

$$Z = \frac{RSA}{100,000}$$

where:

RSA = retail sales area.

A number of variations of Z were subsequently selected for analysis utilizing measurable center characteristics. In each test the revised Z variable form represented a change in one independent variable and a new regression model was tested. Table 12 tabulates the Z components,

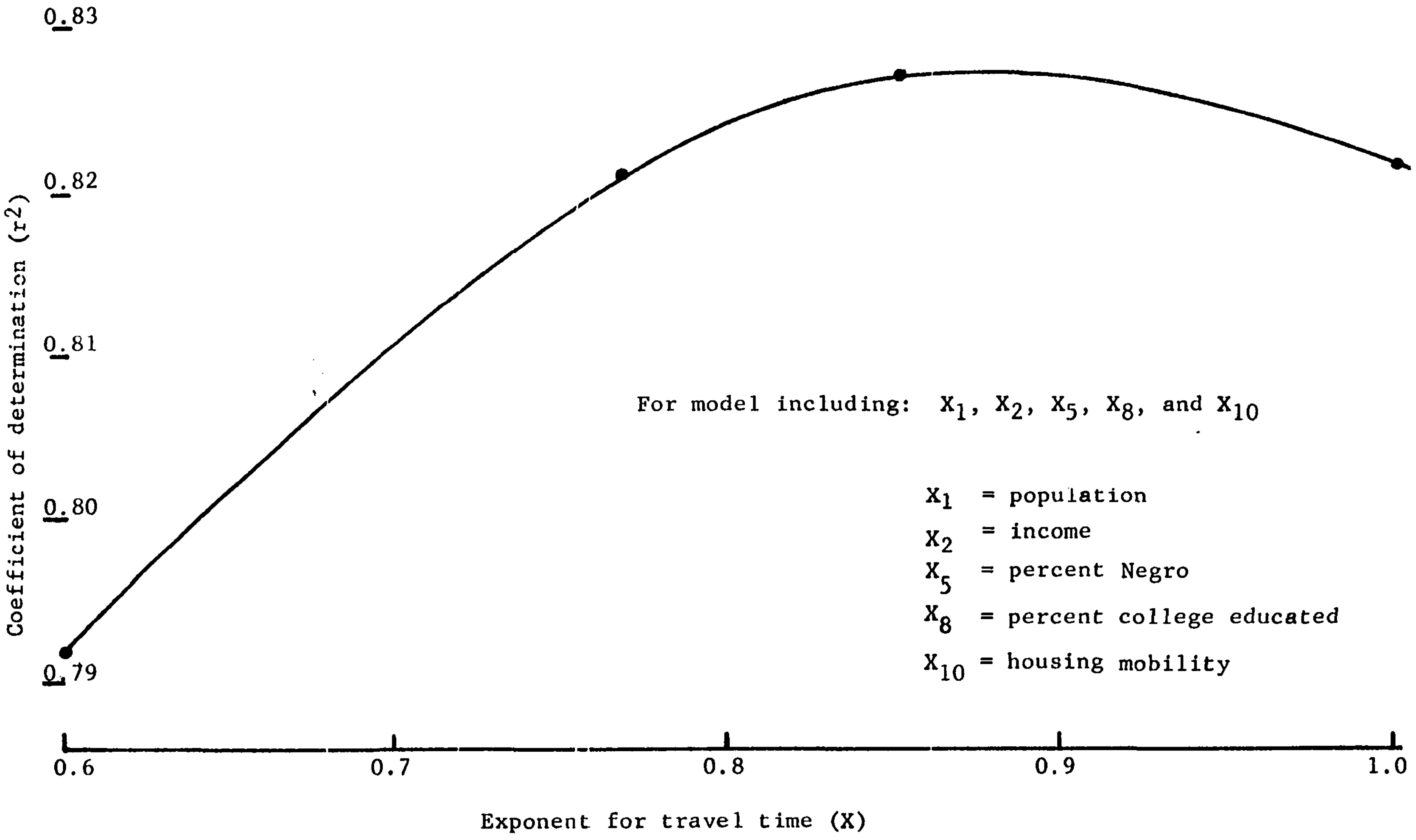


Figure 15. Plot of travel time exponent versus coefficient of determination

Table 12. Summary of the shopping center attractiveness variable analysis

Variable components	Values Z_1	Z_2	r^2	Ratio $Z1/Z2$
$Z_1 = \frac{RSA}{100,000}$	3.88	5.25	0.827	0.74
$Z_2 = \frac{RSA}{100,000}\left(\frac{E}{100}\right)$	11.57	19.52	0.786	0.59
$Z_3 = \frac{RSA}{100,000}\left(\frac{E}{100}\right)^2$	63.01	210.30	0.541	0.29
$Z_4 = \frac{RSA}{100,000}\left(\frac{S}{E}\right)$	0.2824	0.1975	0.674	1.43
$Z_5 = \left(\frac{RSA}{100,000}\right)^2\left(\frac{S}{E}\right)$	1.096	1.035	0.784	1.06

for model: $\left(T_{ij} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{0.85}}\right)$

where:

RSA = retail sales area in square feet

E = number of employees

S = number of stores

values, and ratios. Figure 16 is a plot of the r^2 value versus the Z_1/Z_2 ratio. This relationship was selected as a measure of the ability of each new combination of independent variables to explain the total variance.

Based on observation of Figure 16 it is apparent that the simple term $Z_j = \frac{RSA}{100,000}$ has the highest r^2 value. In the case of competing

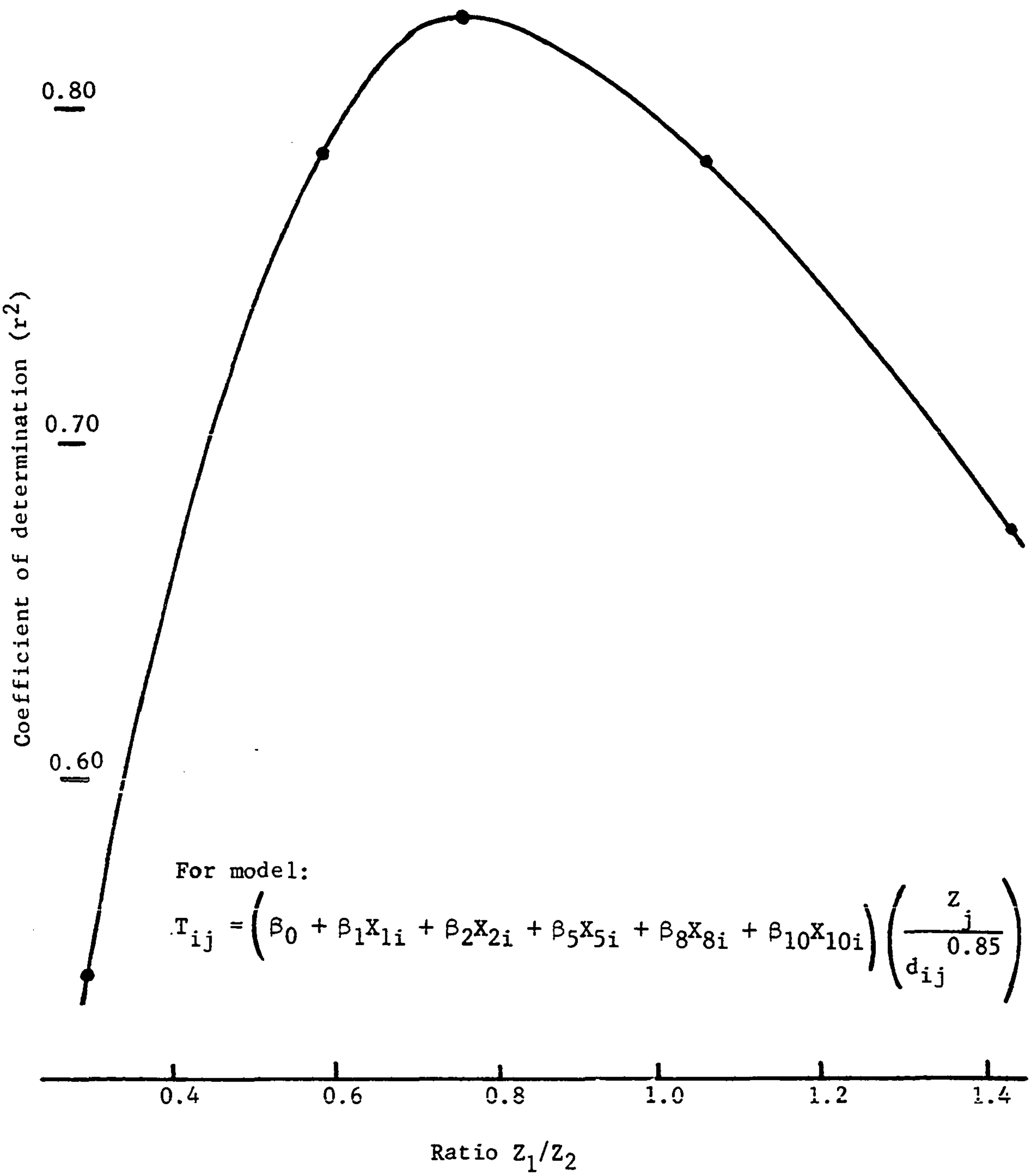


Figure 16. Coefficient of determination versus Z_1/Z_2 ratio analysis

centers with very similar characteristics this observation appears logical. Very likely the other Z variable forms have components with a high degree of association. A good level of service, choice of stores, merchandising ability, and ratio of shopper goods to consumer goods probably exists at each center. Further testing with data from only two centers is obviously not practicable.

The final model has the form:

$$T_{ij} = \left(38.1777 + 0.0720X_{1i} + 0.00069X_{2i} - 1.3918X_{5i} + 3.4677X_{8i} - 1.6250X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{\,0.85}}\right)$$

where all terms have been previously described.

Modification of the Model

The constant in this regression equation has the value of 38.1777. This quantity can be considered relatively large in magnitude since in small zones it constitutes a large portion of the estimate of the dependent variable. It is approximately one-eight of the mean. A modification of the model was obtained to eliminate the intercept. The regression equation was restrained to go through the origin resulting in the regression equation:

$$T_{ij} = \left(0.0735X_{1i} + 0.0093X_{2i} - 1.2327X_{5i} + 2.9979X_{8i} - 1.4011X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{\,0.85}}\right)$$

Summary of the β values and the various evaluation statistics for both models is presented in Table 13. Surprisingly the coefficient of determination is significantly higher for the model with no intercept, the standard deviation is lower, and the F value is higher. Most striking however is the t-test probability for the hypothesis that $\beta = 0$. The significant change regards the β_2 value representing the income variable. For the model with intercept we cannot reject the hypothesis that $\beta_2 = 0$, whereas for the model with no intercept we can reject the hypothesis that $\beta = 0$ at the 95 percent significance level.

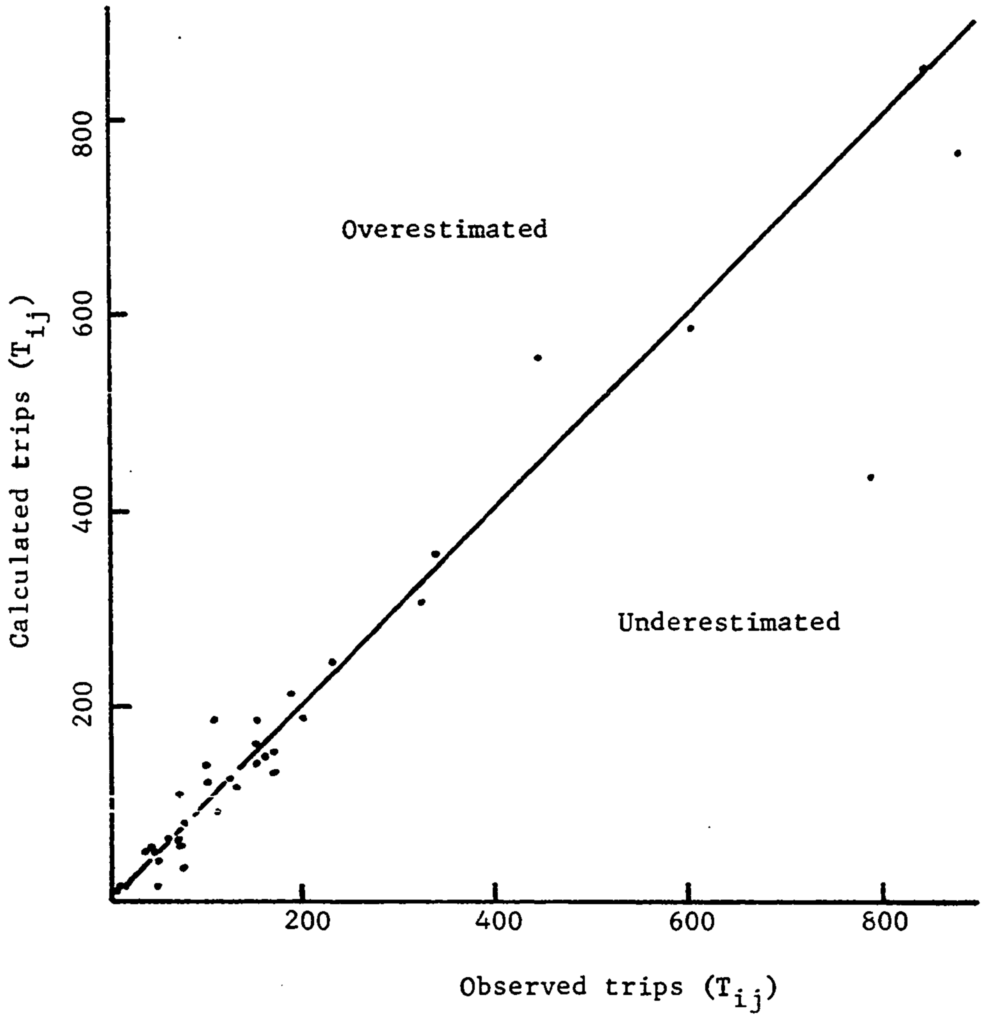
It appears that the modified model with no constant has equal or better statistical validity than the model with an intercept. A remote possibility exists that the statistical evaluations performed in formulating and refining the model might have been different using a model form with no constant. The previously developed statistics apply only to the model with intercept.

As a summary of the overall performance of each model the observed versus the estimated trips were plotted and appear as Figures 17 through 20. A comparison of the same center plots, but with different equations, indicates very little difference in results.

A measure of the relative predictive ability of the model at each center, can be obtained by observing the scatter of the T versus $\hat{T}$ plots. Figure 17 for the College Square center indicates a good fit about the equiangular bisector with one outlying value (census tract number 22 in Cedar Falls). However, observation of Figure 18 for the Crossroad center notes a number of the higher trip values that are

Table 13. Summary of regression equation analysis with intercept and without intercept

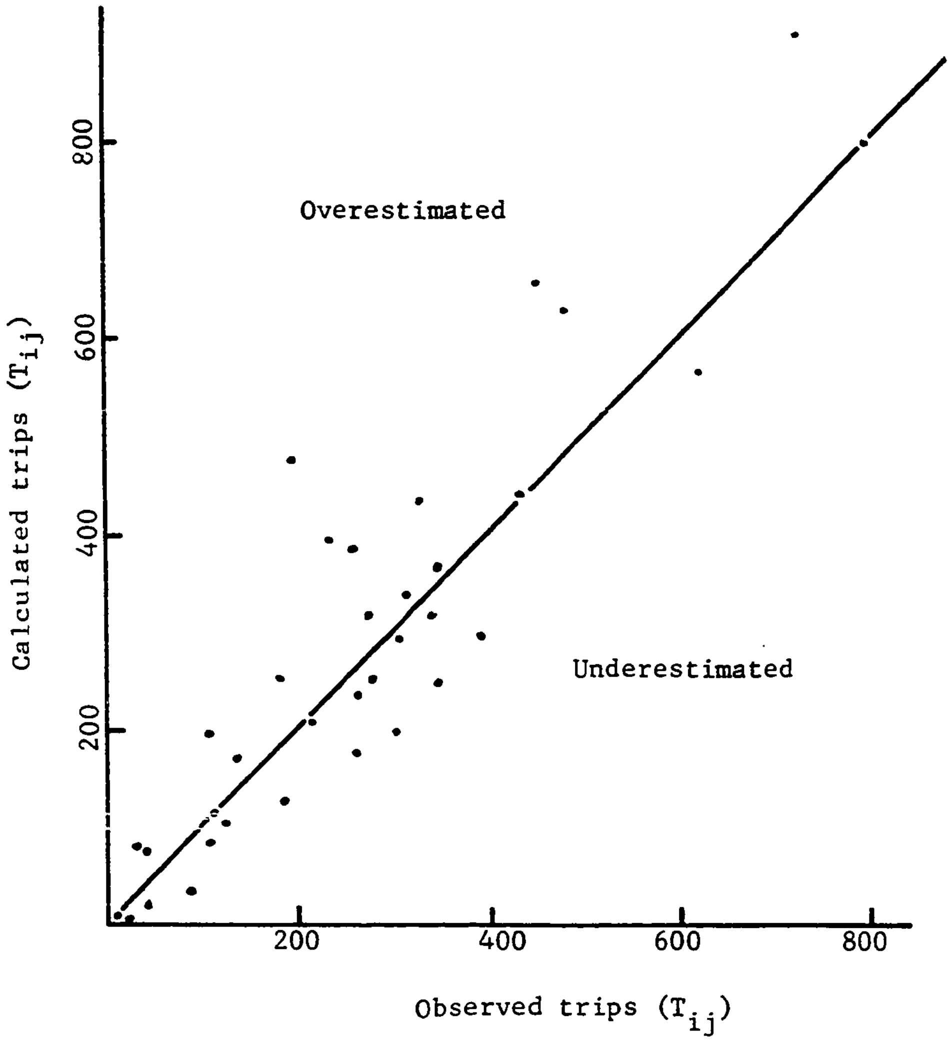
	β value		Probability t for H0: β=0		Statistics	
	with	without	with	without	with	without
β_0	38.177	0	0.6323	--		
β_1	0.0720	0.0735	0.0001	0.0001		
β_2	0.0069	0.0093	0.2876	0.0178		
β_5	-1.3918	-1.2327	0.0599	0.0614		
β_8	3.4677	2.9979	0.0721	0.0707		
β_{10}	-1.6250	-1.4011	0.0352	0.0231		
r^2					0.8268	0.9361
Mean					286.8069	286.8069
Standard deviation					95.2603	94.6832
F value					59.2120	184.6755



For model:

$$T_{ij} = \left(\beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{\,0.85}}\right)$$

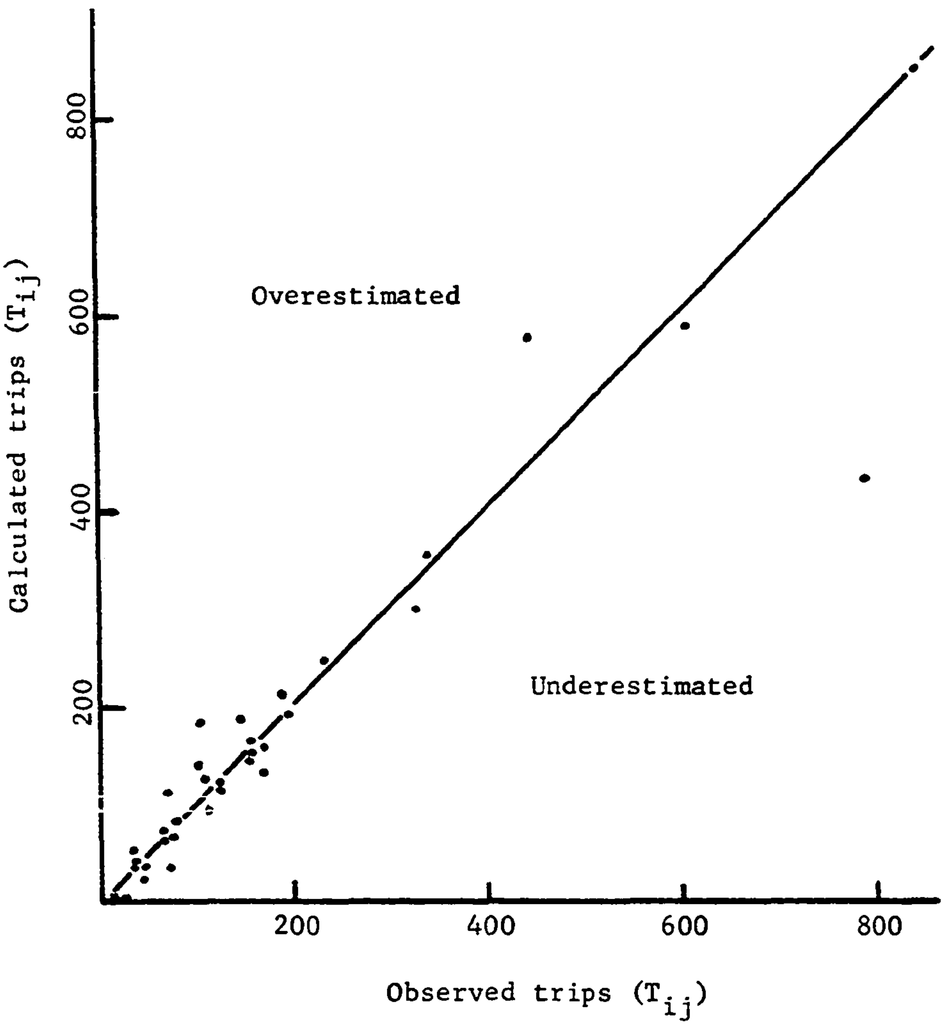
Figure 17. Calculated trips versus observed trips at College Square



For model:

$$T_{ij} = \left(\beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{0.85}}\right)$$

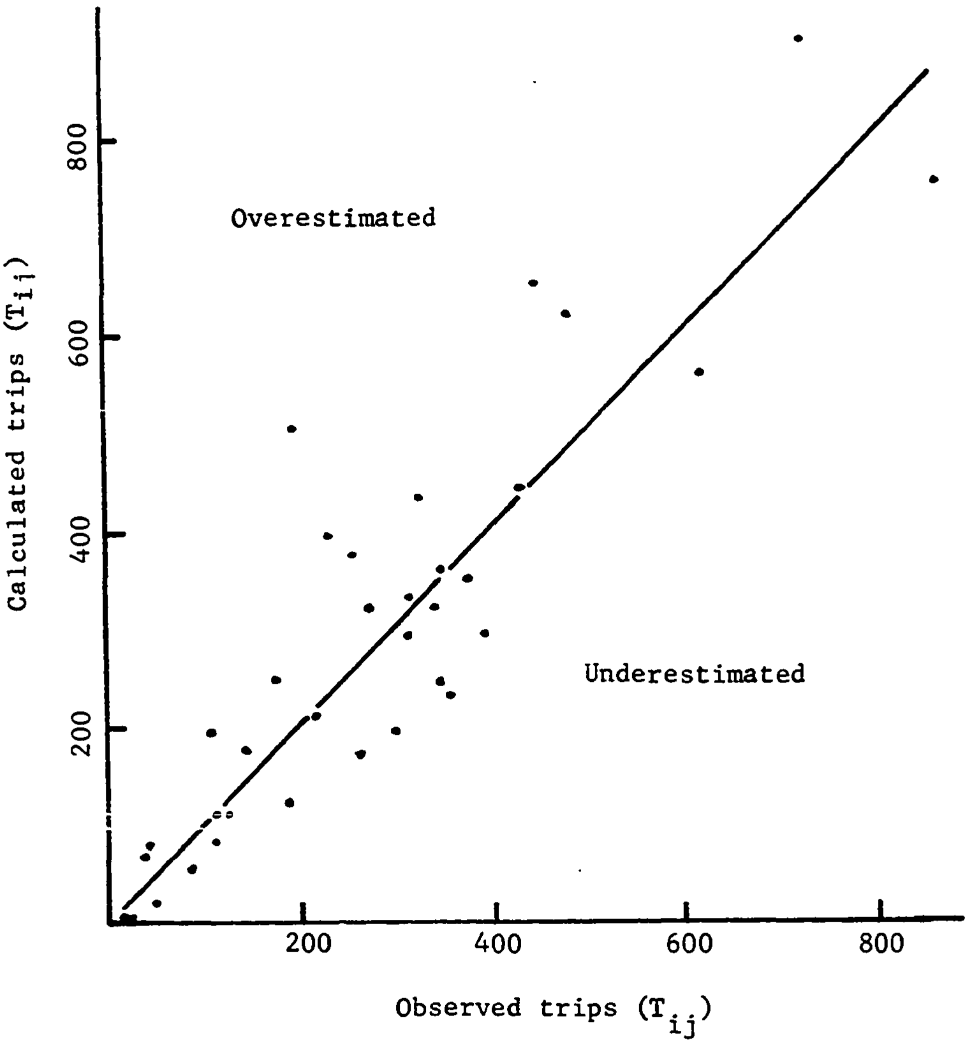
Figure 18. Calculated trips versus observed trips at Crossroads



For model:

$$T_{ij} = \left(\beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{\,0.85}}\right)$$

Figure 19. Calculated trips versus observed trips at College Square



For model:

$$T_{ij} = \left(\beta_0 + \beta_1 X_{11i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{\ 0.85}}\right)$$

Figure 20. Calculated trips versus observed trips at Crossroads

overestimated.

Further investigation of the model form might lead to a refinement in predictive ability. For example, if plots were made of the $(T - \hat{T})$ quantity versus each dependent variable the dependent variable contributing to this overestimation of high values might be isolated. That variable might then be tested in a revised form.

RESULTS AND CONCLUSIONS

The objectives of this study were: to search the literature relative to shopping travel concepts and shopping center attractiveness factors and to identify potential independent variable forms; to obtain meaningful dependent variable data (shopper trips) through a license plate survey; and finally to formulate, analyze and evaluate various models suitable for measuring shopper trips to competing centers.

Vehicle license plate numbers offer a relatively untapped source of travel information. This study was successful in demonstrating the ease in obtaining and processing data from this source. Utilizing unskilled personnel and minimal funds it was possible to obtain the license plate number of each vehicle in the parking lot during a one hour period. As the hour surveys were conducted simultaneously at both centers a basis for direct comparison was obtained. Although financial restrictions precluded a full population survey, the sample size selected provided a meaningful data base. A continuous survey would be feasible if desired.

Translating the recorded vehicle license plate number into a trip interchange generated at a specified census tract origin is time consuming. However, it requires no special training and large volumes of data can feasibly be processed by utilizing a larger number of persons.

This study has demonstrated the suitability of a license plate survey as a data gathering technique. In conjunction with the home address/census tract method of identifying trip origin and stratification of trips a simple, practical, feasible method has been tested for processing relatively large amounts of data.

The final model form developed in this study (with or without intercept) can be considered appropriate to explain travel to competing centers.

$$T_{ij} = \left(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{0.85}}\right)$$

where:

β_0 = 38.1777

β_1 = 0.0720

β_2 = 0.0069

β_5 = -1.3918

β_8 = 3.4677

β_{10} = -1.6250

or,

$$T_{ij} = \left(\beta_1 X_{1i} + \beta_2 X_{2i} + \beta_5 X_{5i} + \beta_8 X_{8i} + \beta_{10} X_{10i}\right)\left(\frac{Z_j}{d_{ij}^{0.85}}\right)$$

where:

β_1 = 0.0735

β_2 = 0.0093

β_5 = -1.2327

β_8 = 2.9979

β_{10} = -1.4011

and for both models:

T_{ij} = shopper trips from census tract i to center j

X_{1i} = population

X_{2i} = median income in dollars

X_{5i} = percent negro

X_{8i} = percent college educated

X_{10i} = percent persons in a different house five years ago

Z = retail sales area of the the center in 100,000 sq. ft.

d_{ij} = travel time from census tract i to center j.

It should be noted that the T_{ij} value obtained estimates trips comparable to the research sample size. It does not automatically yield the average weekday traffic or the peak hour traffic, which is frequently desired. The model is, however, suitable for predicting specific traffic engineering requirements through the application of appropriate factors. Tables 14-17 in the Appendix tabulate the relationship between the sample time distribution and the total trips (T_{ij}) for an initial factor. If an average weekday volume or a peak hour volume is desired it will be necessary to develop an additional factor. This can be based on local shopping center hourly traffic volume counts, or published distributions such as presented by Cleveland (18).

This study has identified the independent variables that in combination form an equation providing the most significant explanation of shopper trips to competing centers in Waterloo, Iowa, in 1972. In the absence of local studies, in another metropolitan area with similar characteristics, this model could be suitable for predicting shopping trips. Limitations on the model's application however should be noted. Social and economic conditions as well as individual behavioral patterns change over time. The conditions that existed in Waterloo in 1972 may in fact have changed in a few years. Continuing studies which might lead to a model revision would be desirable.

The significance of the Negro race (as tabulated in the U.S. Census Reports) within the local ethnic group would need evaluation for the model's use in another city. An atypical city with a large university or a military reservation would require caution.

Further research to refine the model and to study the effect of changes over time in economic and social aspects would be desirable.

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APPENDIX

Table 14. Shopper trips to College Square Center by day of the week and census tract

Census tract no.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Total
1	9	6	10	10	7	5	7	54
2	20	32	21	31	14	22	18	158
3	20	35	23	27	30	16	18	169
4	7	16	19	17	24	19	9	111
5	10	12	7	17	14	11	9	80
6	8	17	11	8	8	5	11	68
7	8	11	8	9	14	13	5	68
8	9	17	15	20	17	18	9	105
9	6	21	7	16	7	16	4	77
10	22	57	28	30	22	25	14	198
11	13	38	27	31	23	13	14	159
12	26	31	17	31	29	21	16	171
13.01	12	38	17	20	13	16	9	125
13.02	19	30	17	17	20	10	12	125
14	39	67	49	57	42	39	28	321
15.01	14	17	13	11	9	6	4	74
15.02	30	52	32	34	34	32	22	236
15.03	39	70	58	56	48	44	24	339
16	21	33	24	23	13	25	18	157
17	21	43	26	37	21	22	15	185
18	4	12	7	9	7	7	4	50
19	14	28	17	16	13	15	14	117
20	14	23	16	15	13	13	6	100
21	19	10	12	11	14	6	4	76
22	102	128	122	127	132	91	84	786
23	119	152	147	132	124	87	87	848
24	65	110	97	107	79	79	67	604
25	58	81	78	71	70	48	37	443
26.01	24	19	16	29	28	21	14	151
26.02	21	3	1	7	3	2	1	38
27	2	0	2	1	0	1	0	6
29.01	6	10	11	5	2	5	7	46
30.01	7	7	9	8	7	4	1	45
30.02	1	0	1	2	2	0	0	6
Total	809	1228	965	1042	903	757	592	6296

Table 15. Shopper trips to Crossroads center by day of the week and census tract

Census tract no.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Total
1	12	12	11	10	19	11	12	87
2	39	60	54	59	46	46	35	339
3	47	52	45	54	55	37	19	309
4	16	23	19	24	28	21	6	137
5	17	22	13	23	19	21	10	125
6	15	16	20	17	24	15	9	116
7	12	14	13	21	20	15	10	105
8	32	38	31	37	40	39	15	232
9	30	29	23	45	37	22	10	196
10	91	89	97	146	135	123	49	730
11	54	70	57	74	80	66	32	433
12	52	64	81	63	88	64	38	450
13.01	77	71	78	78	71	72	33	480
13.02	48	50	48	46	55	30	39	316
14	100	98	78	105	92	80	67	620
15.01	22	30	24	31	31	26	14	178
15.02	31	44	51	55	49	54	17	301
15.03	43	62	49	58	52	48	34	346
16	33	39	50	30	47	47	16	262
17	54	65	50	44	43	53	38	347
18	14	15	12	14	15	20	17	107
19	47	38	33	42	54	36	25	275
20	46	36	58	91	66	67	23	387
21	5	7	8	8	3	8	2	41
22	28	31	43	43	50	48	16	259
23	44	60	41	55	62	33	27	322
24	40	47	36	44	46	38	24	275
25	27	38	34	40	28	37	16	215
26.01	5	8	8	4	9	2	2	38
26.02	6	6	8	6	7	4	3	40
27	3	0	3	3	4	5	2	20
29.01	35	43	42	47	35	46	11	259
30.01	18	30	34	30	36	21	19	188
30.02	3	3	2	2	2	0	1	13
Total	1146	1305	1254	1449	1448	1255	691	8548

Table 16. Daily distribution of shoppers as a percent of total recorded shoppers

	College Square	Crossroads
Monday	13.0	13.4
Tuesday	19.5	15.3
Wednesday	15.3	14.7
Thursday	16.6	16.9
Friday	14.3	16.9
Saturday	12.0	14.7
Sunday	9.4	8.1

Table 17. Hourly distribution of all recorded vehicles as a percentage of each day

Time	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
			College Square				
10:00	22.0	15.4	16.4	21.2	16.3	19.8	----
1:00	26.7	28.8	27.6	24.9	26.5	40.5	52.6
4:00	24.3	25.5	24.6	24.4	25.1	39.7	47.4
7:00	27.0	30.3	31.4	29.5	32.1	----	----
			Crossroads				
10:00	20.0	19.8	22.9	21.8	18.1	26.3	----
1:00	27.3	29.5	27.4	28.7	27.5	40.6	52.8
4:00	23.7	24.8	24.1	23.7	26.8	33.1	47.2
7:00	29.0	25.9	25.6	25.8	27.6	----	----