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Transportation Center

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Travel Distance and Market Size in Food Retailing

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Working Paper
July 1990

UCTC No. 124

The University of California Transportation Center
University of California at Berkeley
TRAVEL DISTANCE AND MARKET SIZE
IN FOOD RETAILING

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July 1990

Abstract

This paper deals with the process of change in urban systems, specifically the changes in the relationships between urban transportation and food retail distribution activities. The dynamic properties of food retailing and transportation systems are identified by tracing location patterns of food stores in Seattle, Washington. Increases in travel demand due to food shopping trips are estimated based on changes in spatial arrangement of food retail activities over the past 50 years. The study suggests that improved transportation services permitted spatial competition of food stores by increasing store size and scope, which in turn influenced the changes in travel patterns for food shopping. Larger stores mean more traffic on principal arterials since higher level stores require higher level services. As stores became larger and larger, store locations grew increasingly farther apart, requiring consumers to travel longer distances for food shopping. As competition heightened, the stores were more uniformly distributed.
TRAVEL DISTANCE AND MARKET SIZE IN FOOD RETAILING

1. Introduction

Traditionally, land use and transportation studies have focused on employment centers, residential locations and home-to-work trips. Research on shopping trips has been largely neglected. A better understanding of the relationships between transportation services and retail location patterns is needed for three reasons: because on some travel corridors shopping trips can be a major factor in contributing to traffic congestion during evening peak hours, because shopping trips are not commonly included in trip generation models, and because the location dynamics of urban retail activities are neglected in the urban transportation planning (UTPS) process.

The objective of this paper is to describe the dynamic properties of retail and transportation systems by examining time series data on food store location patterns with respect to market size (catchment area or population served) and travel distances to and from food stores in Seattle, Washington. Research topics included how patterns of store locations and trading areas changed over time, how far consumers traveled for food shopping, and whether there have been significant shifts in travel demand because of changes in store location. The patterns of store locations are analyzed in terms of spatial competition during the period from World War II to 1990. Shopping travel distances are computed algebraically. Shifts in travel demand for grocery shopping are assessed quantitatively by observing changes in food store locations over time during the past 50 years.

The analysis relied heavily on secondary data, including demographic and economic censuses, retail trade censuses, city and county data books, telephone directories, and information published by retail food industry associations. In this paper, the discussion begins with the review of existing models and the description of the food store locations in Seattle. Then we present the method used in analyzing spatial competition of food retailing in Seattle and associated travel demand, followed by the findings of the study.

2. Dynamic Models of Retail Systems

The previous planning analysis/planning model oriented work most closely related to this paper is that by Harris and Wilson (1978) and Harris, Choukroun, and Wilson (1982).
To simplify referencing, the work will be indicated as HCW. The equation examined by HCW is:

\[ S_{ij} = A_i O_i W_j \exp(-\beta c_{ij}) \]  \hspace{1cm} (1)

Where \( c_{ij} \) is the cost of travel from i to j. \( S_{ij} \) is the flow of retail activity from residences in zone i (say, expenditures flow) to retail activities in zone j. \( O_i \) is the retail demand in zone i. \( W_j \) is size of retail facilities or floor space at j. \( A_i \) relates the attractiveness of the ith zone to the attractiveness of all zones.

\[ A_i = \frac{1}{\sum_k W_k \alpha \exp(-\beta c_{ik})} \]  \hspace{1cm} (2)

Equation 1 is constrained by the condition that demands are met:

\[ \sum_j S_{ij} = O_i \]  \hspace{1cm} (3)

\( \alpha \) and \( \beta \) are parameters, and model specification using power and negative exponential functions is conventional in modern planning models.

Brief remarks on planning models will assist in positioning HCW's contribution. The environment for planning analysis is, of course, the city and the growth and development of the city over some time horizon, say, 20 years. The city is divided into analysis (traffic) zones, and analysis models seek to project the evolution of land uses in those zones and the zone to zone travel for which transportation capacities may be required. Land use and travel patterns change as time passes.

Considering the questions explored by HCW, if there were no economies of scale in the production of services, production in each zone would match the market, i.e., expenditures by those residing in the zone. (Leaving aside retail purchases by non-residential activities or from non-residential travel bases; for example, noon-time retail shopping by employees in an office building and the purchase of office supplies by a small firm.) The presence of economies of scale in the production of services differentiates their locations in zones.
The exponent of \( W_p \alpha \), captures the scale effect. As expenditures in a zone increase (possible store revenue increases), there is a shift from "store not possible" to "store possible" (a location equilibrium point) and then to a situation where "more than one store is not possible, surplus expenditures go out of the zone." This description is for one zone; the city is a collection of zones. As a result, the pattern of equilibrium has to be considered over multiple zones. There is also the question of the stability of patterns. HCW examine equilibrium/stability issues and models for deriving equilibrium store location patterns.

Other matters examined by HCW include location behaviors when store operators attempt to maximize profits, and behavior when there is a consideration of consumer surplus maximization. The latter extends the measure of merit beyond lower prices to the consumer resulting from store scale economies to the transportation costs incurred by travellers, the \( C_{ij} \)s.

As stated in the beginning of this review of the HCW work, the work is most salient in the transportation planning model and analysis literature. It suggests how insights and findings from the thesis might find their way into planning practice, i.e., via a model of the HCW form. However, the HCW work is not where this paper begins. Rather, the paper has an observed behaviors beginning point, in short, how have store location and store and travel characteristics changed and why? So this paper is aimed at knowledge that might assist the specification of HCW-like formulations.

In HCW's work, expenditure flows are a result of store locations and sizes. Travel is some function of expenditures: the frequency of trips, travel distances, and mode choices. However, this paper analyzes only the changes in travel distances to and from food stores because frequency of trips to grocery stores has remained constant over the past 50 years, and almost all customers use automobiles for grocery shopping. The effects of this shopping travel on transportation facilities are measured in vehicle miles travelled and traffic volume on urban facilities. The following sections present location behavior of grocery stores in Seattle.

3. Reason for Selecting Seattle

The hilly topography of Seattle has led to well-defined patterns of residential settlement. These patterns were also influenced by early economic activities in water
transportation, lumber production, fish processing, and shipping. The topography and natural waterways divide the city into three parts: North, West, and Central-South. Most areas of Seattle are predominantly single-family residential, except the central portion of the city, which contains the central business district (CBD) and the high- and medium-density residential neighborhoods.

Seattle proper is an old Western U.S. city, more than 130 years old. It has gone through various evolutionary stages, from a collection of early local communities to the "street-car city" and from the street-car era to massive suburbanization and highway expansion of the post-World War II period. Seattle’s downtown has been a major regional office hub and retailing center. After World War II, Seattle suffered its greatest economic difficulties during the early 1970s, when the Boeing Company, the region’s top employer, reduced its work force. The area has long since recovered from that economic downturn and is currently undergoing unprecedented population growth, even though population growth within the Seattle city limits is relatively stable.

The city’s geographic boundaries are well defined. The hourglass-shaped city is bordered on the west by Puget Sound and on the east by Lake Washington. Topography and natural waterways divide the city in ways that offer convenient analysis of data, particularly at the neighborhood level. Seattle is somewhat linear, running north and south, and thus the major transportation corridors are nearly all in the north-south direction.

Since the early 1960s, there has been no major growth in the city proper either in terms of size or overall density. Relative population stability has been achieved by increased development of multi-family housing to offset the lower average family sizes. The city values its urban heritage, and there are active citizens’ groups advocating slow-growth policies which are in conflict with increased apartment development.

In short, Seattle provides a study site where settlement patterns have been relatively stable in recent decades. Its selection as a study site was to take advantage of the stability of variables other than transportation that might affect store sizes and locations.

4. Patterns of Food Store Location

In the Seattle metropolitan area, the number of supermarkets declined dramatically over the past few decades. The floor space of food retail stores per 10,000 persons also decreased because of improved retail technologies, including computerized inventories and
just-in-time delivery systems. During the 1940s, a large number of stores (322 stores serving a 1940 population of 368,000) served relatively small market areas (one store per 1,100 persons). Supermarkets ranged in size from 8,000 to 12,000 square feet, offered fewer than 2,000 items, and were about one quarter the size of present-day supermarkets. During this time, superettes were interchangeably used as supermarkets as far as store sizes were concerned. A typical Safeway store during World War II was 50 feet wide and 140 feet long with a 50 feet by 50 feet parking lot on the frontage of the store off the main road. By the early 1950s, the store size had nearly doubled.

By 1990, the number of supermarkets declined to 45, serving a population of 496,000 persons, or one store per approximately 11,000 persons. Today, many supermarkets exceed 30,000 square feet of selling area and carry more than 20,000 items. The sizes of stores increased, and trading areas grew over time. Improvements in transportation and larger store size made it difficult for small and independent retail grocers to survive, and nearly all small independent stores were replaced by multi-line large chain supermarkets. This trend is expected to continue beyond the year 2000 (Table 1 and Figure 1). Multi-line food chains refer to those stores carrying many items, not only those produced by their own firms but also those produced by other firms.

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
<th>Household</th>
<th>NoStores</th>
</tr>
</thead>
<tbody>
<tr>
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<td>368302</td>
<td>126354</td>
<td>322</td>
</tr>
<tr>
<td>1950</td>
<td>462440</td>
<td>154511</td>
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<td>1960</td>
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<td>73</td>
</tr>
<tr>
<td>1990</td>
<td>496254</td>
<td>234382</td>
<td>45</td>
</tr>
</tbody>
</table>

Figure 1. Persons per Supermarket and Households per Supermarket, Seattle

Data source: Seattle Telephone Directory
As in many cities, some Seattle retail stores tend to agglomerate while others tend to separate spatially. Such behavior is principally the result of a decision to increase market share, either by locating adjacent to compatible stores or by locating away from competitive stores. As found in Marysville (Garrison, 1959), our study confirmed that supermarkets have typically located with compatible retailers such as drug stores, bakeries, and laundromats. But we also found that convenience stores, such as 7-Eleven stores, seek locations in close proximity to supermarkets (Seattle telephone directory; 1985, 1988). Convenience stores seek to capture a portion of supermarket patrons, such as those in a hurry for only a few items or those seeking fast-food snacks.

In the 1940s, as many as five or six small supermarkets competed within the same neighborhood business district. In more recent years, the newer and larger supermarkets tend to locate apart from each other, leading us to believe that food retailers are seeking locations based on the ability to dominate the market in their immediate area. Such behavior is also found in other urban areas in the U.S. (Nelson, 1958) and even in Ljubljana, Yugoslavia, where political and market structures are completely different from the U.S (Rogers and Martin, 1969). The following section will present an overview of the theories relevant to the location behavior of food stores.

5. Some Aspects of Location Theory

The main branches of location theory are concerned with two conditions (Norman, 1979): when demand is fixed, how should stores be located in order to minimize the marginal cost? Alternatively, how will a store locate and what market areas will they control with given knowledge of demand when they are in direct competition?

The first question, the ‘least cost’ approach to location theory, is based on the work of Weber (1929). Weber investigated exogenous factors influencing location of industries, for those agglomerating and for those deglomerating. Agglomeration or deglomeration are indirect factors by which firms can take advantage of location. Agglomeration of industries is driven by large-scale production through technical apparatus or labor organization while deglomeration of industrial location is due to the increase in rent from the result of agglomeration (Weber, 1929). Isard (1956) and Alonso (1964) subsequently addressed the agglomeration effects of industries on land rent and the associated effects of transportation costs.
The second question of location theory stems from two schools of thought: the central place theory of Losch and Christaller and the "interdependence theories" of Hotelling and Smithies. While the Weberian approach is concerned with a heterogeneous market with fixed consumption, Losch's work assumes a homogeneous plane with uniformly distributed consumers. Given that the size of the individual market is determined by the relationship between production and demand conditions, different industries will serve different size markets. When these variably sized markets are superimposed on a plane, we can observe a hierarchy of production centers. The work of Garrison and Berry (1958) later showed that a hierarchy of central places will also emerge in a heterogeneous economic space.

While the central place theory addresses the "spatial implications of imperfect competition," interdependence theories are concerned with "the spatial implications of non-collusive oligopoly" which assumes few agents are involved in the market (Norman, 1979). The early work in "spatial oligopoly" was carried out by Hotelling (1929) and later by Smithies (1941) in the context of "duopolistic competition" within a well-defined market area. Hotelling's spatial oligopoly is narrated in his story of the ice cream vendor. When two vendors are locating their stores in a linear market, the first one will settle at the center of the market. The second vendor entering the market will choose a location immediately next to the first vendor because this location will strategically allow capture of one half of the entire market. This type of equilibrium is said to be quite different from the consumers' welfare equilibrium (Scott, 1971), where the objective is to minimize the total aggregate transportation costs of customers. In the consumers' welfare instance, retailers will locate their services each in the middle of one half of the linear market.

When there are more than two retailers involved, stores tend to disperse and Hotelling's competitive equilibrium will then vanish. In a case where three stores are involved, two retailers will locate their stores at the quartile points and the third store will be located at any point between them (Chamberlin, 1933). Since retailers will gain no benefit by being located closely together, each retailer will "choose the mid-point of his indifference range," and thus stores are "distributed at equal intervals along" the linear market. In contrast to Chamberlin's view, Lerner and Singer (1937) believe that stores carrying homogeneous goods tend to cluster in pairs so long as there is no threat of price competition.
According to Lerner and Singer, when a single retailer enters into a new market and has no competition, the store should be located at the center of the trading area to capture the entire market. When the second retailer enters a market in which a store already exists (a la Hotelling), the store will be located as closely as possible to the existing one. When a third store enters this market, it will also locate as closely as possible to the two previous ones, if it can capture a sufficient share of the market.

If three stores are actively competing for market shares, the store in the most central location within the trading area will be pushed out and will relocate at the outer edge of that trading area. In effect, the relocated store will achieve a greater market share than the remaining two stores. As the market in the middle grows, the remaining two stores move away from each other until they are at the quartile of the market where two are at one quartile and the third at the other. It was observed that stable equilibrium can not be reached when three or some greater number combinations of stores are involved in the market (Lerner and Singer, 1937). If a fourth retailer enters the market, each pair of stores will locate in each quartile. Thus each store will serve one quarter of the market. Since there is no reason for any of these stores to change their strategic positions, a stable equilibrium is reached. Similar processes go on as new stores enter the market. The market tends to work towards establishing a stable equilibrium.

Store location behavior in Seattle was far too complex to describe according to the economic principles of spatial competition. In the case of Seattle, new stores in an existing trading area forced some stores to relocate and others to permanently close. Furthermore, many players such as independent grocers and land owners were involved in supermarket location decisions, making it difficult to trace the process by which store location patterns were created. Therefore, we used the point pattern mapping technique to analyze spatial competition of food retail stores.

6. Point Pattern Maps

Geographers often study point pattern maps to learn about the processes by which those patterns are created. Boots and Getis (1988) classified point patterns as spatial ‘randomness,’ ‘clustered pattern,’ and ‘regular pattern.’ They believe that these patterns are derived from identifiable economic agents or from chance events. Boots and Getis assume that the theoretical pattern of complete spatial randomness (CSR) could be
generated by a 'homogeneous planar Poisson point process' which assumes that every location has an equal chance of occurrence, receiving a point (building a store in our case), and the selection of a location is completely independent from other points. Such a pattern would occur only if the environment were completely undifferentiated, the equal chance assumption. 'Clustered patterns' are those in which points are grouped to create clusters of activities on a plane and 'regular patterns' are those in which points are uniformly spread out with equal spacing between points. When the conditions of the CSR process changes, either by competition or by some economic forces, we can expect clustered and regular point patterns. 'Agglomeration' and 'association' resulting from attraction will produce a clustered pattern and 'segregation' and 'repulsion' from diffusion or competition will likely generate a regular pattern.

Point patterns can be analyzed in two ways. One is to measure the dispersion of points relative to the area. The other is to measure the arrangement of points relative to each other. In this paper, the concern is with dispersion. How are supermarkets spatially distributed in relation to the market areas that they serve? In Seattle, spatial patterns of stores varied significantly over the past decades. While stores evolved from one type of location pattern to another, they organized in different intermediate patterns of spatial order. The point pattern maps shown in Figure 2 are for North Seattle taken at four different time slices. Only four out of 11 maps (11 time slices at five-year intervals) studied were shown because only four different point patterns could be observed. For instance, the point pattern maps taken at 1940 and at 1945 showed little difference because of the stability of the market during World War II.

Borrowing Boots and Getis' definition, the point pattern maps representing four stages of development in North Seattle are classified as random cluster (1940-1950, relatively stable); uniform cluster (1955-1965, very stable); random pairs (1970-1985, unstable); and uniform singles (1985-1990, stable). The process of change in point pattern maps in Seattle from random clusters to uniform singles can be shown with the data on the range of market sizes at each time slice. The statistical tests supporting the above classification are discussed later in Section 8. In this paper, the point pattern maps of Seattle are described in terms of spatial competition and dispersion of store locations relative to market areas. Attention is given to stable and unstable point patterns. Stable and unstable patterns are defined in two ways: one refers to the process of change in the context of time, and the
other refers to the strategic positions of stores in the context of space which deals with the physical locations of stores. The term used in this section refers to the latter definition.

Figure 2. Point Pattern Maps - North Seattle

Stage 1. Random Clusters
1940 - 1950

Stage 2. Uniform Clusters
1955 - 1965

Stage 3. Random Pairs
1970 - 1985

Stage 4. Uniform Singles
1985 - 1990
Stage 1. Random Clusters (1940-1950)

During and after World War II, stores in Seattle displayed a randomly clustered pattern. "Random cluster" means that clusters of points are randomly dispersed. Between 1940 and 1950, the location patterns of stores are relatively stable. There was a reduction in the number of food stores during the war, but the number of stores between 1945 and 1950 was virtually unchanged. The range of market sizes during this period varied significantly which indicates that there was also a large variation in store sizes. The location behavior of random clusters represents the destabilization stage of the development process of spatial patterns in food retailing.

Stage 2. Uniform Clusters (1955-1975)

Between 1950 and 1955, the point pattern maps were transformed into uniform clusters. This was the period when sharply increased automobile ownership and road improvements enabled suppliers to explore larger scale food retail activities. In the late 50s and the early 60s, as the stores established a standardized scale, the location pattern was transformed into an orderly dispersed pattern of clusters of stores. So this pattern is described as "uniformly clustered." Uniform is defined as relatively even spacings between stores from which an orderly pattern can be identified. This represents the stage where spatial patterns of food stores are somewhat stabilized.

At this stage of development, clusters of stores are distributed in an orderly fashion. The strategic positions of stores are relatively stable, meaning that each store has found its own market niche. The supply side of the market is relatively stabilized in terms of the types and location of stores serving a given residential population.

Stage 3. Random Pairs (1975-85)

By the 1970s, supermarkets began searching for new scale economies. The 70s and 80s patterns represent random pairs; however, the 80s pattern had pairs of stores more orderly dispersed or in patterns close to uniform pairs. "Random pairs" means that pairs of points are dispersed without any order. During this period, clusters of stores were transformed into pairs of stores. Supermarket location patterns in Seattle around the 1970s very much resembled Hotelling's model of competitive equilibrium behavior in which relatively large trading areas are served by two closely located supermarkets. The
competitive oligopoly model (Norman, 1979) contends that in order to maximize profit, this spatial arrangement allows store owners to capture up to one half of the entire market so that a stable spatial equilibrium can be reached.

There are two possible explanations for such a pattern. It might be that among the stores shown in those clusters, the two having the best ability to attract consumers, either by price competition or amenities, were able to hold their positions. Or it may be that smaller and older stores were replaced by larger and more attractive stores. It appears that the latter case holds in the case of Seattle. New stores entering the market had to work with more consumer inducement strategies to compete with existing stores. They used larger scale and scope economies (meaning larger stores with a greater variety of items), improved cleanliness, and specialized services. The new stores seemed to have chosen locations close to existing stores in order to draw upon their clientele. By this time many of the older and less competitive stores had been replaced by larger and more attractive modern supermarkets. One of the scale effects worth noting is that many small stores were in effect replaced by fewer large stores.


Today pairs of stores have almost disappeared, and the pattern consists of a dispersion of single stores in a semi-orderly fashion. "Uniform single" means individual stores dispersed in orderly or semi-orderly fashion. As economies of scale change, the point patterns also change. Consequently, as the size of stores increases, stores are increasingly farther apart.

During the mid- to late-1980s, intense competition for and shifting of market shares among retail grocers forced another change. Pairs of stores were reduced to single stores. As one of the two stores increased in scale (making store size larger in order to reduce marginal cost), the other had to give up its location. A similar situation occurs when two stores are consolidated under one roof. In theory, the same space under one roof (instead of under two roofs) can effectively enlarge the market size because one large store can operate at a lower cost per unit than two stores (Progressive Grocer, 1989).

The consolidation process stems from stores’ opportunity to sell a variety of both food and non-food items. This process consequently results in a more dispersed and uniformly spaced pattern. If consumers are uniformly distributed, this process will eventually reach
supply side market equilibrium (an optimal spatial distribution of stores). When one store loses, the surviving store serves the entire market. Where such displacement occurs, the store that expands and provides more services prevails. This process suggests that the food market in Seattle has become one with oligopolistic characteristics.

It seems apparent, though, that spatial patterns of food store locations cannot be easily explained by microeconomic principles, mainly because the outcome of the competitive process depends largely on assumptions about the location behavior of suppliers.

7. Formulas for Market Size and Travel Distance Computation

Earlier in the paper, we stated that a major goal of this research is to trace a history of travel distances in food shopping. This section is devoted to a discussion of the methods used in generating time-series data on food store locations in Seattle and in defining market areas for the computation of travel distances to and from food stores.

When locations of stores and density of population are known, the analysis process involves market area partitioning exercises. The solutions of these exercises yield the populations served or the physical dimensions of market areas from which average vehicle miles travelled to each store can be computed. Several techniques are available. In some cases, simple techniques such as hand sketching to obtain the approximate boundary of the market area would be appropriate. On other occasions, a simple algebraic formula such as $kA^n$ would be acceptable. ($k$ is constant value derived from the shape of market and $A$ is the areal dimensions of market.)

For more precise measures of travel distances, some partitioning problems may be solved with ordinary linear programming (English, 1972; Cliff, 1981; Love, et.al., 1988). To define market size and calculate travel distances, the partitioning problems reported here were solved algebraically. The data used for this analysis are the address files of stores from the telephone directory at five year intervals, eleven time slices from 1940 through 1990. To define the boundary of market areas and to measure the travel distances to and from stores, each store location, $j$, was digitized with respect to $x$ and $y$ coordinates for each time slice. New stores entering the market were noted to separate them from stores remaining from the previous time slice. Residential locations, $i$, are subdivided into small square cells, in size similar to the city block size, and these cells are also digitized with respect to $x$ and $y$ coordinates. The net total distance reported is the sum of the distances
to js from each i which, in effect, represents a residential block. Market areas are defined by calculating the shortest distances to stores. Two formulas were used: one measured and compared changes in total travel distances over time with population density (Equation 1), the other measured net increases in travel distances with respect to the physical sizes of market areas (Equation 2).

**Equation 1**

\[ D_j = \sum_{i \in S_j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \]

\[ S_j = \left\{ i \mid (x_i - x_j)^2 + (y_i - y_j)^2 + \min_{j=1,n} \left((x_i - x_j)^2 + (y_i - y_j)^2\right) \right\} \]

\[ D_{j_{\text{avg}}} = \frac{D_j}{\sum_{i \in S_j} \rho_i} \]

- \( \rho_i \) = population in zone i
- \( D_j \) = total travel distance to j
- \( S_j \) = set of zones assigned to store j
- \( D_{j_{\text{avg}}} \) = average travel distance to j

**Equation 2**

If \( \rho_i = \rho \), and \( \rho \) is constant then

\[ D_j = \rho \sum_{i \in S_j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \]

\[ D_{j_{\text{avg}}} = \sum_{i \in S_j} \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{D_j} \]

- \( b_j \) = number of blocks in j
When calculating travel distances, we assume that distance equals the Euclidian distance between stores and residences. The network is made up of links between origins, \( i \) (households), and destinations, \( j \) (stores). This assumption obviously does not replicate urban travel, but it was made to simplify the analysis. Distances were measured for each time slice in five year increments from 1940 to 1990. The Euclidian distance between \( i \) to \( j \) is approximately 23-30 percent shorter than the city block distance. The results of the analysis using the above formulas are discussed in the subsequent section.

8. Market Size and Travel Distances

This section reports on changes in the size of food markets and in travel distances to and from food stores in Seattle. The results reported are based on Equation 2, which does not consider population density because Equation 1 yielded similar results.

**Market Size**

As expected, food store market sizes increased over time. In 1940, food stores served the median market size of 19 blocks, or 400 to 500 households. In 1990, the median market size is 185 blocks, or about 3,000 households. The growth in market sizes is shown in Table 2 and Figure 3. As noted in Section 6, the range of market sizes differs among samples examined. Variations among food store market sizes in each time slice are measured by examining the ratio between the average size of markets and the standard deviation of market sizes. If the ratio (\( \tau \)), the standard deviation divided by the average store size, is relatively large or \( \tau > 1 \), a large variation of market sizes exists. Randomly clustered patterns create a large variation of market sizes. The low \( \tau \), on the other hand, creates more uniformly distributed patterns. Figure 4 shows the four stages of development based on the statistical analysis of market size variations (Table 2). As mentioned earlier, market sizes are measured by the number of cells, with the cells being equal to urban blocks. The low ratio between the average standard deviation of market sizes in the late 1980s indicates that store distribution patterns are relatively uniform. In the 1940s and 50s, there was greater variation in market size than in the 1980s. Food stores served from 1,000 to 3,000 people. In recent years, each supermarket serves roughly the same population (11,000 persons), which implies that these stores have been able to establish a stabilized
market by isolating themselves from competing stores. (In the metropolitan Seattle area, Safeway dominates the market. That chain achieved the market solution.)

Table 2.
Variations of Market Sizes
North Seattle

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<th>Year</th>
<th>Number Average</th>
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<td>58.167</td>
<td>33.33</td>
<td>6518.77</td>
</tr>
<tr>
<td>1970</td>
<td>72</td>
<td>60.143</td>
<td>55.00</td>
<td>6926.24</td>
</tr>
<tr>
<td>1975</td>
<td>54</td>
<td>63.789</td>
<td>76.00</td>
<td>8252.26</td>
</tr>
<tr>
<td>1980</td>
<td>33</td>
<td>66.826</td>
<td>97.00</td>
<td>46253.26</td>
</tr>
<tr>
<td>1985</td>
<td>11</td>
<td>69.548</td>
<td>117.00</td>
<td>9257.66</td>
</tr>
<tr>
<td>1990</td>
<td>22</td>
<td>72.543</td>
<td>120.50</td>
<td>16347.90</td>
</tr>
</tbody>
</table>

Figure 3.
Average and Median Market Sizes
North Seattle

The findings of the analysis support the assertions we made in the earlier discussions in this paper. That is, the recent food store location patterns in North Seattle are more uniformly distributed than were the patterns in the 1940s. Figure 4 indicates that between 1950 and 1955 store patterns suddenly changed from random spacing of store locations (producing varied market sizes) to relatively uniform spacing. Local spatial competition could be the cause of this phenomenon. The rate of reduction in the number of stores during this time period, however, was not as high as during other time periods (Figure 5)

Travel distances

Changes in average travel distance by households per time slice are shown in Figure 6. The average travel distance during this time period increased by 71 percent. Conversely, the variance in length of travel significantly decreased. The dip shown in the travel distance curve between 1955 and 1965 may indicate that the shorter average travel distances experienced in these years is largely related to the spatial re-arrangement of
supermarket locations. Note that the number of food stores has decreased over time. In the earlier years (1940s) stores were clustered in such a way as to create longer distances than in the pattern shown in the 50s. Decreased food shopping distances in the 1950s do not seem to have a direct relationship to transportation services. Seattle is a relatively old city; in the 1950s few funds were available for municipal road improvements. The city’s local and arterial street infrastructure had already reached maturation and the basic transportation network was already established. There were modest changes in a few selected locations to accommodate the north-south I-5 freeway, which opened in 1962, and the State Route 520 freeway, opened in 1963.

Figure 4. Variations of Market Size
North Seattle

Figure 5. Number of Food Stores
North Seattle

Figure 6. Average Food Shopping Travel Distances
One-way trip by household, Seattle
Shifts in Traffic Volume

Food stores choose locations with respect to land use patterns and transportation networks. Store locations are to a large extent constrained by land use regulation and land availability. Prior to 1960, land zoned for commercial use could be utilized in many ways and stringent, activity-specific development regulations did not exist. Subject to the commercial land use constraint, store locations were largely influenced by economic factors and market forces. For accessibility and visibility, supermarkets were generally built at intersections of major arterials. This trend has continued and the same locations have often been used over the years by many owners. A comparison of supermarket location patterns from 1940 and 1989 suggests that an additional 30 percent of the food shopping traffic is now on principal arterials (Table 3).

Table 3. Arterial Classifications and Traffic Volume in North Seattle

<table>
<thead>
<tr>
<th>1942 Street Classifications</th>
<th>1988 Street Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary: DTV NS TS %</td>
<td>Primary: DTV NS TS %</td>
</tr>
<tr>
<td>Roosevelt Way 19000 9</td>
<td>Northgate Way 31200 1</td>
</tr>
<tr>
<td>Aurora Ave 19000 6</td>
<td>Aurora Ave 36000 1</td>
</tr>
<tr>
<td>15th Ave NW 18000 2 17 (15.04)</td>
<td>Lake City Way 37700 1</td>
</tr>
<tr>
<td>Secondary:</td>
<td>15th Ave NW 30800 1</td>
</tr>
<tr>
<td>NE 55th St (NA) 6</td>
<td>NE 145th St 28200 1</td>
</tr>
<tr>
<td>N 45th St (NA) 2</td>
<td>NE 45th St 25200 1</td>
</tr>
<tr>
<td>Market St (NA) 8 16 (14.16)</td>
<td>Market St 20,300 1 7 (31.82)</td>
</tr>
<tr>
<td>Tertiary: number of stores  80 (70.80)</td>
<td>Secondary:</td>
</tr>
<tr>
<td>Total number of stores      112 (100%)</td>
<td>Roosevelt Way 10200</td>
</tr>
<tr>
<td></td>
<td>NE 65th St 18400 1</td>
</tr>
<tr>
<td></td>
<td>Green Lake 14100 1</td>
</tr>
<tr>
<td></td>
<td>Greenwood 13700 1</td>
</tr>
<tr>
<td></td>
<td>San Point Way 15800 1</td>
</tr>
<tr>
<td></td>
<td>Fremont N 10300 1 6 (27.27)</td>
</tr>
<tr>
<td></td>
<td>Tertiary: number of stores  9 (40.91)</td>
</tr>
<tr>
<td></td>
<td>Total number of stores      22 (100%)</td>
</tr>
</tbody>
</table>

Difference between 1940 and 1990:
\[((31.83\%+27.27\%)-(15.04\%+14.16\%))=29.89\%

DTV: Daily traffic volume
NS: Number of stores
TS: Total number of stores

9. Conclusions

This paper was concerned with how transportation services affect the location behavior of supermarkets at the micro (local) level and, conversely, how location decisions of supermarkets influence travel demand on food shopping. As mentioned earlier, food retail outlets responded to the availability of automobiles by increasing store size to capture a larger market share (Yim, 1992). Consumers, in effect, had also benefitted from the efficiency of larger stores with the convenience of one-stop shopping. As the cost of
transportation declines, the service areas (catchment areas) will continue to expand. Consequently, as service areas expand or as demand density increases, cost of stores will decrease. Since it is to the seller's advantage to reduce the marginal cost of store operation by increasing its size, store expansion is expected to continue until market saturation is reached or until there are decreasing returns from increases in scale and scope.

The major effects of spatial competition in food retailing are the increased travel distances for food shopping and the shifts of traffic volume from local streets to principal arterials. Although the market for automobiles is nearly saturated, trends indicate that the retail food industry may continue to seek even greater economies of scale and scope by increasing store size (i.e., superstores or combination stores) in the future. Consequently, spacing between food stores will rise and consumer travel distance for grocery shopping will increase by the square root of the store size. Unless traffic congestion creates a problem, market density will continue to follow the current path.

This study is predominantly an empirical one. Theoretical and policy aspects have been largely untouched. A broad range of research remains to be done to strengthen the theoretical framework as a means to study the process of change among urban retail activities. As an example, our study supports Nelson and Winter's view about the limitations of the orthodox theory of duopoly behavior in describing spatial competition. As Nelson and Winter contend, the neo-Schumpeterian terms of competition might have been a better choice for this type of study than the neo-classical equilibrium concept.

Finally, the relationship between food retail and transportation systems observed in this paper confirms previous research (Allen, et al., 1981; Arthur, 1988; Garrison, 1987; Harris and Wilson, 1978; Harris, et al., 1982; Meyer, 1974; Webster, 1988) that spatial arrangement of urban activities are dynamic. Static-equilibrium-based UTP models would not merit long-term application for trip generation forecasts.

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Yim, Youngbin, "The Effects of Transportation Services on the Scale of Food Retailing," *Working Paper,* 1992, University of California Transportation Center, UCTC No.112.