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Shopping Trips and Spatial Distribution of Food Stores

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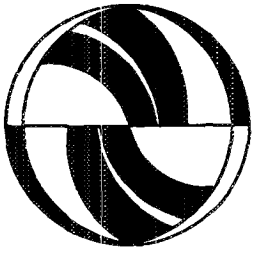
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### Author

Yim, Youngbin

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**Shopping Trips and  
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Youngbin Yim

Working Paper  
UCTC No. 125

**The University of California  
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Berkeley, CA 94720

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**University of California  
Transportation Center**

108 Naval Architecture Building  
Berkeley, California 94720  
Tel: 510/643-7378  
FAX: 510/643-5456

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# **Shopping Trips and Spatial Distribution of Food Stores**

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## **SHOPPING TRIPS AND SPATIAL DISTRIBUTION OF FOOD STORES**

Youngbin Yim  
Institute of Transportation Studies  
109 McLaughlin  
University of California  
Berkeley, CA 94720

### **Abstract**

This is an empirical study of food shopping trips in Seattle, Washington. In travel forecasting models, land use activities and transportation systems are assumed to be in static equilibrium. This paper deals with the dynamic nature of urban systems, specifically the interaction between food retail distribution systems and transportation systems. The research questions were: how long does it take these systems to reach an equilibrium and to what extent do transportation systems respond to location choice of food stores? In this paper, we examined changes in travel distances to and from food stores with respect to the location of food stores. In theory, if stores are optimally located with respect to the market area served, then store size and market size should be in equilibrium. To observe the equilibrating character of retail and transportation systems, actual store location patterns were compared with optimal store location patterns at several points in time using travel distance measures. The study showed that transportation systems and food retail distribution systems adjusted to each other and the process of adjustment took several decades to reach an equilibrium. During the past 50 years, store size and travel distance converged at only one point in time, around 1985. The findings of the study suggest that dynamic-equilibrium based models would provide a better predictive capability for long-term projections than static-equilibrium based models.

# SHOPPING TRIPS AND SPATIAL DISTRIBUTION OF FOOD STORES

## 1. Introduction

Current transportation planning models are limited to short-term application. A major weakness of the models is that spatial organization of urban activities and associated travel requirements are assumed to be in static equilibrium. These unrealistic assumptions are built into the models mainly because of the lack of experience in developing operationalized models based on dynamic situations. Until the late 1970s, the research focus was primarily on static situations of urban systems. Lately, several researchers have attempted to describe non-equilibrium states of complex urban systems using differential equations or probability theory (Allen, 1981; Arthur, 1988; Beaumont and Clarke, 1981). Nevertheless their studies are mostly theoretical and, on the whole, there has been limited experience in using dynamic models for replicating urban systems.

The objective of this paper is to investigate self-organization processes of food retail outlets with respect to transportation costs to and from stores in Seattle, Washington. The dynamic of the relationships between retail distribution and transportation services has an equilibrating character as travel and store characteristics adjust to each other. Over the long run, there is a trend toward ever larger stores and longer travel distances until store size and travel distance converge. The study of Seattle showed that as stores grew larger, the service areas of their markets expanded, and store locations were spatially reorganized from a randomly clustered to a more uniformly distributed pattern (Yim, 1990). Consequently, as the patterns became increasingly uniform, longer trips were required for routine grocery shopping.

In theory, when stores are optimally located with respect to the market area served, store size and market size reach an equilibrium. Since market size is a function of store size and if market size tends to adjust to store size, the question is how closely do actual store location patterns resemble optimal patterns under equilibrium, considering the transportation cost? In this paper, we examine three aspects of the dynamic properties of transportation and retail systems: 1) the equilibrating character of store size and market

size measured in transportation cost, 2) the amount of time required to reach an equilibrium between transportation and retail systems, and 3) the rate of change two systems need in order to adjust to each other.

The motivation of this study is to invite discussions on the direction of research and development efforts in large scale models for transportation planning. The effectiveness of the models depends on the realistic assumptions used in these models; thus, the study was conducted with the expectation that the findings reported in this paper would encourage research in the dynamic process of urban systems.

In this paper, the discussion begins with the equilibrium concept of retail and transportation systems followed by the equilibrating character of store size and market size, measured in transportation distance, in Seattle. The paper then reports on the rate of change in grocery store locations over time in Seattle.

## 2. Concept of Equilibrium

The study most pertinent to this paper is the work of Harris, Choukroun, and Wilson (HCW). The HCW work on balancing mechanisms between store sizes and market sizes is the beginning point for discussion in this paper. HCW's conjecture is that market demand equates store size. In other words, suppliers will provide retail floor space according to the revenue generated. This paper starts with that assumption and also assumes that equilibrium between store size and market size is reached by way of spatial competition (Yim, 1990). HCW shows the relationships between retail center size and market size as:

$$\begin{aligned}\sum_j S_{ij} &= O_i \\ S_{ij} &= A_i O_i W_j \exp(-\beta c_{ij}) \\ A_i &= 1 / \sum_k W_k^\alpha \exp(-\beta c_{ik})\end{aligned}$$

Where  $S_{ij}$  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  $i$ th zone to the attractiveness of all zones.  $c_{ij}$  is the cost of travel from  $i$  to  $j$ .  $\alpha$  and  $\beta$  are parameters of

the model.  $\alpha$  represents the scale economies of retail centers by which consumers can benefit from the greater choices or lower prices offered at large retail centers. The value of  $\alpha$  is measured by consumer taste or their awareness of the benefits from scale economies of large retail centers.  $\beta$  specifies the relationship between retail size and market size (purchasing power) over space measured by transportation accessibility. Changes in the values of  $\beta$  will depend on changes in transportation facilities or technology such as the availability of automobiles or an improved network.  $k$  is a conversion factor from capacity units of floor space to revenue units. When technological developments reduce the marginal costs of retail centers  $k$  will change with or without increasing scale economies.

The key points of the HCW investigations are that the balancing mechanism between store and transportation systems depends on the values of the exponent  $\alpha$  of the floor space  $W_j$  and the value of the coefficient  $\beta$  of the transportation distance. If  $\alpha > 1$ , two equilibrium points exist and if  $\alpha = 1$  or  $\alpha < 1$ , only one equilibrium point exists. If  $k$  is sufficiently large in the case of  $\alpha > 1$  or  $\alpha = 1$ , no equilibrium exists.

Considering the revenue and retail floor space balancing problem as discussed above, we examined how store size is correlated with revenue or sales volume. Using the 1988 cross-section data aggregated at the state level, setting sales volume ( $S_v$ ) in dollars as the dependent variable and average store floor space ( $S_s$ ) in square feet as the independent variable, the data were regressed. When the annual sales volume per household was regressed against the average store size, a weak correlation was found. However, a strong correlation was found when the annual total sales volume ( $S_v$ ) was regressed against the total floor space ( $S_s$ ) of supermarkets. A linear equation (Figure 1) fits as well as a log-linear equation (Figure 2).  $S_v$  is measured in dollars and  $S_s$  is measured in square feet.

Linear equation:

$$S_v = -54.51 + 0.00037S_s$$

(127.78) (0.0000069)

$$R^2 = 98.40$$

The intercept is insignificant in this case because the error term of the intercept is much greater than the value of intercept.



Log-linear equation:

$$S_v = e^{-7.42} S_s^{0.97}$$

Intercept standard error = 0.276

Slope standard error = 0.0173

$R^2 = 98.53$

The power of  $S_s$  is close to 1. This indicates that the relationship is linear.

Figure 1. Store Size and Sales Volume, Linear Relationship (1988 state data)

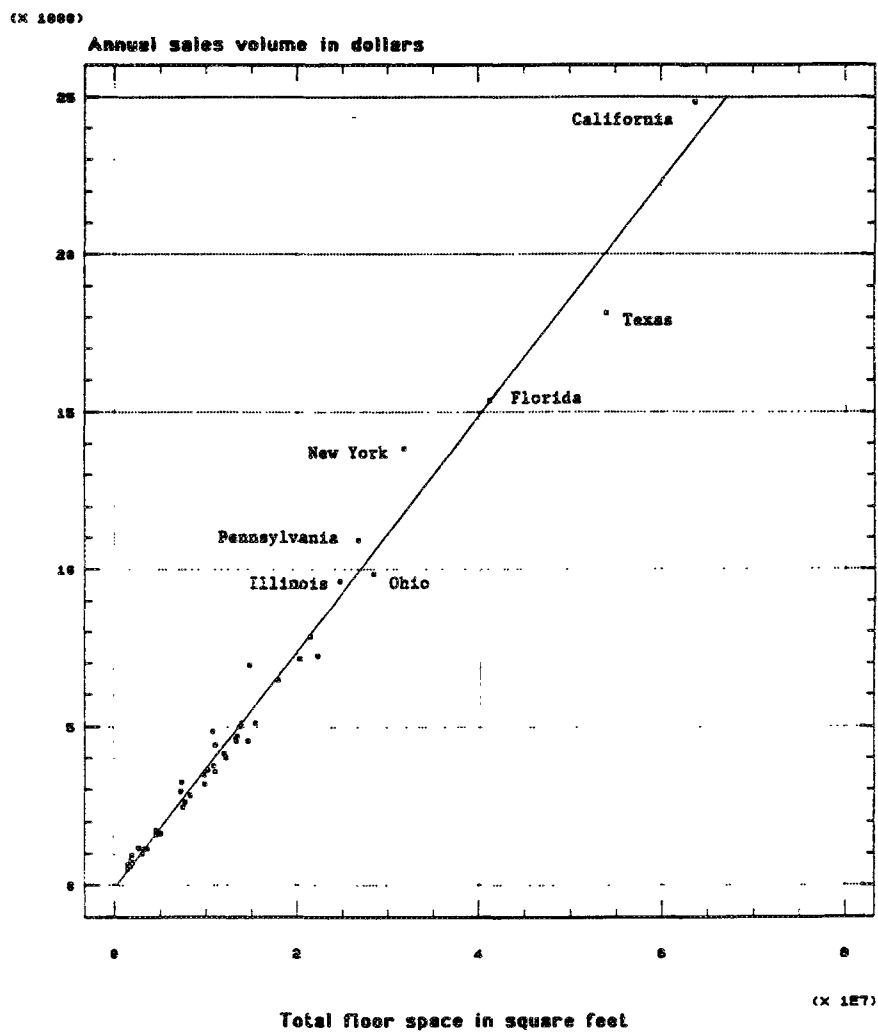
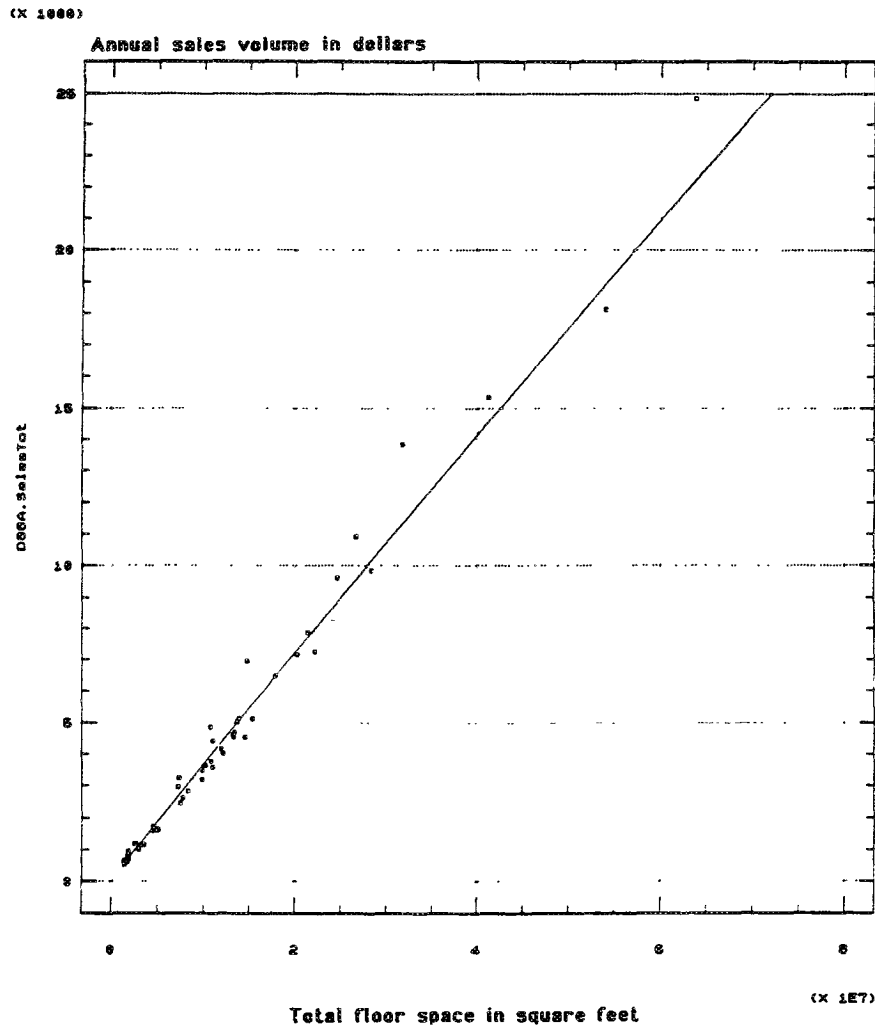


Figure 2. Store Size and Sales Volume, Log-linear Relationship (1988 state data)



These findings suggest that, at the macro level, there is no scale effect,  $\alpha=1$ . Macro level processes are those seen at state or regional levels. The subsequent step of the investigation is to examine how the micro level processes are played out in terms of balancing store size and market size. That is to compare the actual and optimal store locations to investigate whether store size and market size are in equilibrium at any given time. Market size in this paper is measured in areal size represented by average travel distance (miles) to and from stores while the HCW model measures store revenues (dollars). To present the travel measurement approach, the following sections will discuss the methods used in computing actual and travel distances to and from food stores and calculated travel distances under optimal conditions.

### **3. Equilibrium of Store Size and Market Size**

In this section, we investigated the equilibrating character of store size and market size by comparing the actual travel distance to and from stores with the calculated distance under optimal store location. To trace the location behavior of stores, time series data from 1940 through 1990 on supermarket locations in Seattle were analyzed in five year increments.

#### **3.1. Actual travel distances**

The actual travel distances to and from stores are measured in the northern portion of Seattle city proper. This area was chosen because its geographic boundaries are well defined and the settlement patterns are relatively unchanged. The population density of this area has been constant over the past few decades and there has been little improvement of transportation services since the early 1960s. Its selection as a study site was to take advantage of the stability of growth and development, other than transportation that might affect the location choices of grocery stores.

In computing an actual average travel distance at a given time slice, the conditions presented in store locations are treated as a set partitioning problem. Since the locations of stores and the density of population at each time slice are known in this case, the solutions derived from set partitioning exercises would yield the physical dimensions of market areas from which the miles traveled to and from stores can be computed. In calculating travel distances between stores and residences, travel distances are assumed to be equal to the Euclidian distance. To simplify the analysis the network is assumed to be made up of links between origins,  $i$  (households), and destinations,  $j$  (stores), although this assumption does not truly replicate urban travel. The formula used in calculating the actual travel distance to the nearest store is as follows:

If  $\rho_i = \rho$ , and  $\rho$  is constant then

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

$$D_{j\text{avg}} = \sum_{i \in S_j} \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{b_j}$$

- $\rho_i$  = 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
- $b_j$  = number of blocks in j
- (X and Y are coordinates with respect to store locations)

The above formula gives the net increases in travel distances with respect to the physical sizes of market areas since there has been virtually no change in population density over the past few decades in North Seattle. In 1940, a total of 112 grocery stores served 43,900 households. The average one-way travel distance to grocery stores was 0.477 miles. In 1990, 22 supermarkets served 114,600 households. Each household now travels, on the average, 0.703 miles to a supermarket. This is an increase of 47% in trip length to and from grocery stores. However, if the cumulative effects of the changes in household size and travel distance to stores are considered, the net increase in travel distance is 285%. When the changes in travel distance are measured for the area within Seattle city proper as a whole, the trip distance to grocery stores has increased by 71%.

### 3.2. Store location problem and assumptions

To compare actual and calculated travel distances over time, the optimal size of the market must be found for each time slice. The criterion for optimal size of the market is minimization of the sum of transportation and store costs (Beckmann, 1968). The method used in this study is similar to the formula shown in the well-known warehouse location problem. In simplest form, the warehouse location problem is to find the locations of  $n$  supply warehouses which minimize the total shipping costs (Newell, 1973). A more

general formulation is to find  $n$  and the location coordinates that minimize the sum of transportation and warehouse costs. One might think that the store location problem is not quite identical to the warehouse location problem since the cost of transportation in the warehouse problem is borne by the shipper. Whereas, in the case of the store location problem, customers pay their own transportation costs. These distinctions, however, vanish if the store location problem is treated as a social welfare maximization problem.

In computing the optimal size of food markets, another methodological concern is the obtainability of the globally optimal spatial patterns of store locations. With the methodological limitations at hand, the best outcome one could hope for is nearly-optimal solutions for rigidly specified conditions. Therefore, the formula used in this study is a solution for a local optimal market size. These methodological limitations are reflected in the calculated costs considered in the computation of travel distances to and from food stores. In this study, costs are assumed to be a linear function of distance and the same for all travellers.

Similar to the warehouse location problem, transportation cost increases with distance while store cost decreases as store size increases. Thus, the trade-off between transportation distances and store sizes is to balance transportation cost and store cost.

The conditions assumed in calculating the optimal market size are:

- Total transportation cost is a function of the location of all points, residences and stores.
- Cost of stores is a function of store size.
- Operating cost of stores is a function of sales volume.
- Size of store is proportional to the market area served.
- The location of each store is at the center of its market.

In addition, it is assumed that consumers are utility maximizing individuals whose objectives are to minimize their total expenditures for any given food purchase. The total expenditure is the cost of purchasing goods plus the general transportation cost (expenditures plus travel time cost). Travel time is assumed to be proportional to distance. It is also assumed that individual customers will patronize a store, say Store 1, as long as

they believe that the sum of their costs is less than the cost of patronizing Store 2 for similar goods.

$$TC_1 < TC_2$$

$$tc_1 + sc_1 < tc_2 + sc_2$$

Where,  $TC_1$  is total cost to Store 1,  $TC_2$  is total cost to Store 2,  $tc_1$  is transportation cost to Store 1,  $tc_2$  is transportation cost to Store 2,  $sc_1$  is store cost in store 1, and  $sc_2$  is store cost in store 2. In principle, if scale economies exist, retailers should be able to offer lower prices for the same goods and to offer a greater variety of choices as stores grow larger. If the transportation cost is reduced, the opportunity increases for retailers to expand the size of their stores. The lower the price or the greater the variety of goods, the larger the radius of the market that can be captured. These principles are broadly interpreted in the formula used in calculating an optimal market size.

Relatively similar size stores serve urban regions regardless of city size even though there is a strong indication that high density neighborhoods are served by fewer numbers of stores than low density neighborhoods. To simplify the formula and for the reasons stated above, the areal size of all  $A_i$  are assumed the same and the demand density of all  $A_i$  are equal. Using the above assumptions, the local optimal solution for the market size of each store was found.

### **3.3. Method of travel distance calculation under optimal store location**

This section presents the method used in calculating the optimal size of a food market. The size of a market is defined as the areal size served by an individual supermarket. As previously stated an optimal market size is the area found by minimizing the average store cost plus the average cost of transportation. The global minimum cost can be calculated by integrating over the entire market area.

## 1) Computation of Average Transportation Cost

For simplicity of calculation, the shape of the market is assumed to be circular. Market areas of different shapes, whether circles, hexagons, triangles, or squares, have different average travel distances, but the differences are relatively insignificant in travel distance computation (Newell, 1973). If the ideal shape of a market area is a circle, and the area  $A_i$  is served by a single store which is located at its center, the average travel distance  $D_{avg}$  for a circular market is  $2R/3$  where  $R$  is radius of a circle. The average transportation distance is the total distance divided by the area since we assume that the density of population is uniform.

The cost of transportation is assumed to be a function of the distance traveled and proportional to the Euclidean distance of a region (Beckmann, 1968). Thus, the average transportation cost  $T_{avg}$  per customer for a uniformly distributed demand density for a circular region,  $A_i$ , can be written as:

$$\begin{aligned} T_{avg} &= D_{avg} t \\ &= 2Rt/3 \\ &= 0.376 tA_i^{1/2} \end{aligned}$$

In this study,  $t$  represents the gasoline cost per mile. Gasoline cost is considered instead of the owning and operating costs of automobiles because we are mostly concerned with marginal changes in transportation cost. During the last 20 years, automobiles have become smaller and the efficiency in gasoline mileage has increased. The efficiency in gasoline mileage was considered in the computation of the average transportation costs.

While the size of households has been decreasing, the number of automobiles per household has been increasing. This is mainly because more women have access to automobiles. Over the same period of time, the marginal cost of gasoline has been decreasing. The decreased marginal cost of gasoline plus the ready availability of automobiles has resulted in increased demand for urban highways and arterials.

## 2) Computation of Average Store Cost

Store cost is the sum of appropriately discounted land, construction, and operating costs. The annual cost of stores,  $S_c$ , varies according to store size and location. In most urban areas, land value is assumed to increase as one approaches the city center. Although there are economies of store size, construction cost is relatively constant over an area because the unit cost of construction has little variation within each region. Unit operating cost is a decreasing function of store size and demand density is proportional to the size of population. Therefore the formula for computing the total store cost,  $S_c$ , can conceptually be described as:

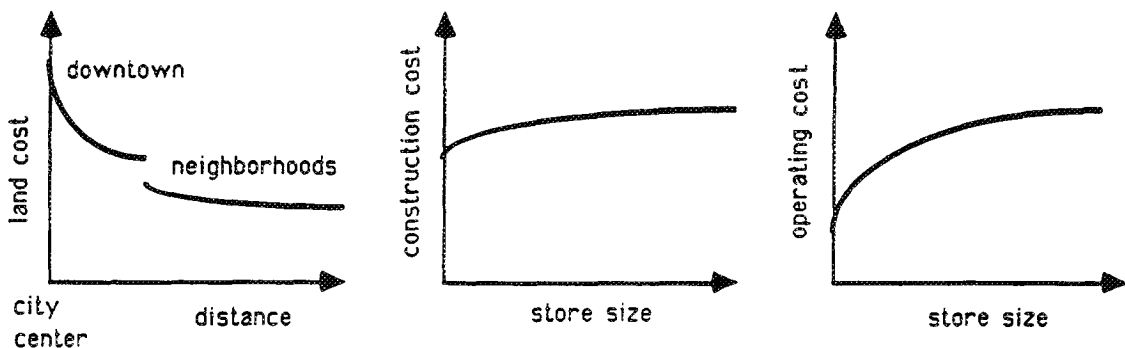
$$S_c = L_c + C_c + C_o$$

Where

$$\begin{aligned} L_c &= d^\alpha, & \alpha < 0 \\ C_c &= s^\beta, & 0 < \beta < 1 \\ C_o &= s^\gamma, & 0 < \gamma < 1 \end{aligned}$$

$L_c$  = annualized land cost  
 $C_c$  = annualized construction cost  
 $C_o$  = annualized operating cost  
 $s$  = store size in square feet

Where  $\alpha$ ,  $\beta$ , and  $\gamma$  are parameters. These parameters are based on the assumed relationships between costs and specified variables as shown below.



Land value has an inverse relationship to distance from city center (Alonso, 1964). Economies of scale in supermarket construction is assumed to be insignificant because of construction type. Operating cost, however, is proportional to the size of stores.



As is true of most urban areas, until the 1960s there was a bountiful supply of commercially zoned properties along major arterials. Land for possible sites for supermarket development was found in all areas of Seattle residential neighborhoods. The land price between commercial and residential uses varied significantly but land price within neighborhood commercial zones did not vary much. Supermarkets during the study period were located in the outer ring of the urban center, mostly in residential neighborhoods. For this reason, only operating cost is considered in the store cost computation. The cost,  $S$ , is a function of area and density of demand. The average store cost per customer for a given store size,  $S_{avg}$ , can therefore be written as:

$$S_{avg} = \frac{C_o(R)}{\pi R^2 \rho}$$

Where  $C_o(R)$ , unspecified log-linear function of  $R$ , is operating cost of the store and  $\rho$  is the density of demand. Since the density of demand is assumed to be constant, the average store cost for a given size is the operating cost divided by the area ( $A_i = \pi R^2$ ) of the market.

In calculating operating cost, we considered labor cost only, because it is the largest operating expense and varies significantly according to the size of the store. Other operating costs such as energy or advertising are proportional to the quantity of labor. For the purpose of fitting the data to a function, a section of parabola was used. The reason for using this method instead of statistical determination of the store cost curve is the limited data available on store operating costs.

#### 3.4. Calculated travel distance under optimal store location

The calculated value of an optimum market size for  $A_i$  is obtained by minimizing the sum of the average transportation cost and the average store cost. The average transportation cost is  $2Rt/3$  and the average store cost is  $C_o(R)/\pi R^2 \rho$ . Since the total average cost ( $TC_{avg}$ ) is:

$$TC_{avg} = \frac{2}{3}Rt + \frac{C_o(R)}{\pi R^2 \rho}$$

To find the radius  $R$  for the optimum market size for which  $TC_{avg}$  is:

$$\frac{d}{dR} \left[ \frac{2}{3}Rt + \frac{C_o(R)}{\pi R^2 \rho} \right] = 0 \quad (1)$$

This implies:  $2\pi R^3 \rho t + 3RC_o'(R) - 5C_o(R) = 0$

To solve for  $R$ , find  $R > 0$ , such that equation (1) is satisfied. The average travel distance is obtained by  $2R/3$ . Table 1 illustrates the calculated area ( $A_i$ ), radius ( $R_i$ ), and average travel distances ( $D_{i,avg}$ ) for the optimal sizes of a market at five year time intervals. The calculated average transportation and store cost for each time slice is shown in Figures 3 through 6.

Figure 3.  
Calculated Store Costs 1940-1965

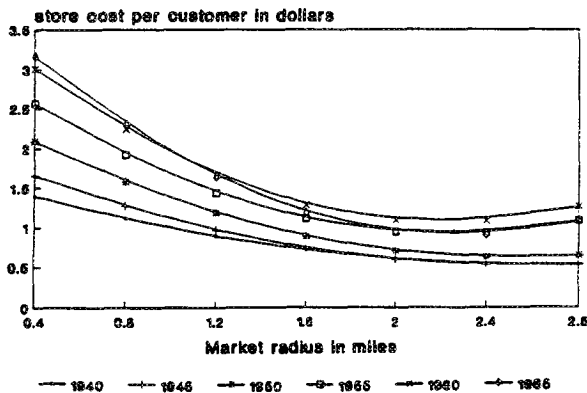


Figure 4.  
Calculated Transportation Cost 1940-1965

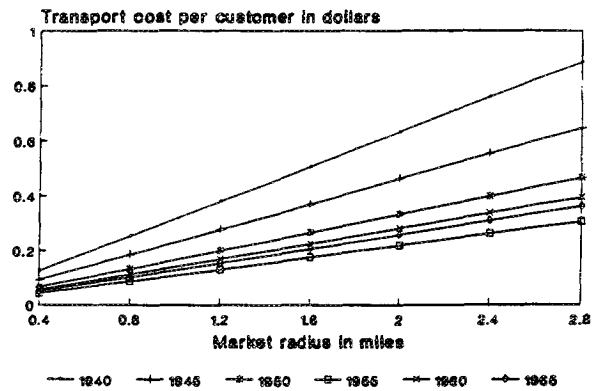


Figure 5.  
Calculated Store Costs 1970-1990

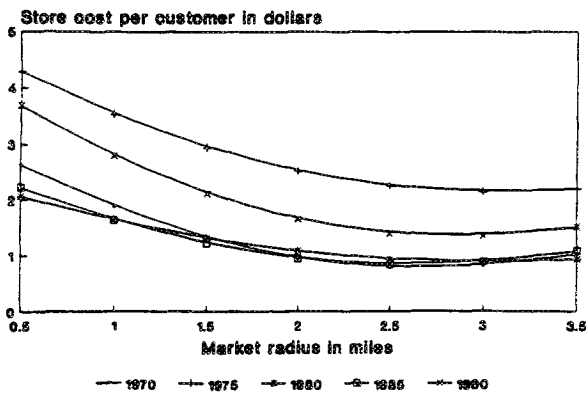
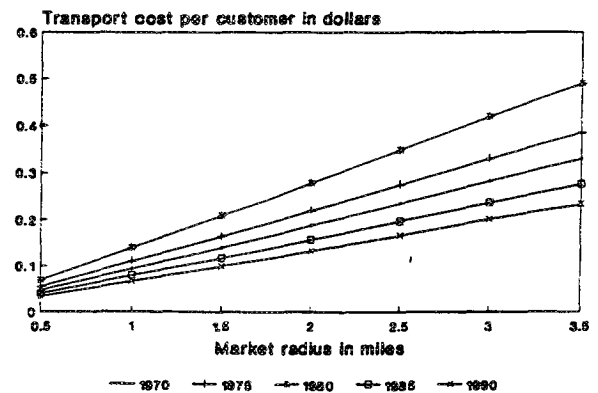


Figure 6.  
Calculated Transportation Cost 1970-1990



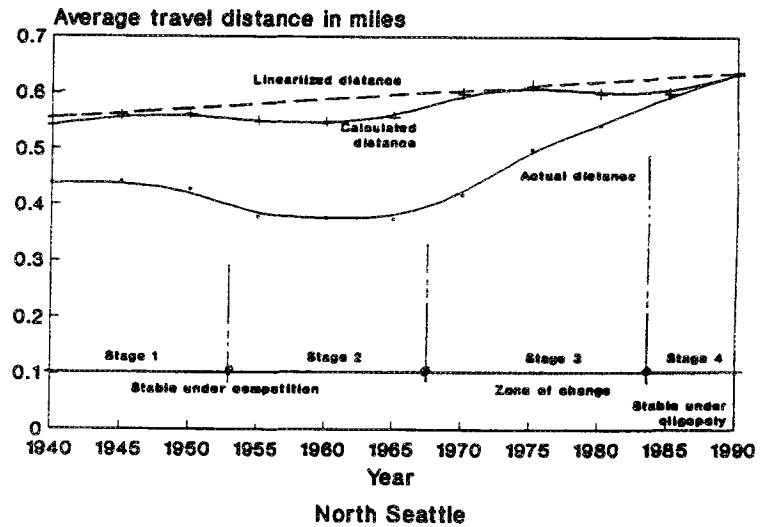
### 3.5. Comparison between actual and calculated travel distances

Figure 7 shows the actual and calculated average travel distances. Several observations can be made from Figure 7. Prior to 1985, the actual distances traveled to supermarkets were much shorter than the distances would have been if the stores had been located optimally. Until about 1965, the large number of independent stores resulted in the shorter travel distance. There was a period of reduction in the number of stores during the 1970s until the actual travel distance reached the same level as the calculated distance in 1985.

Table 1.  
Calculated Values-North Seattle

Year	Market AreaSqMi	Radius Miles	AvgTravel DistMiles
1940	2.485	0.889	0.593
1945	2.450	0.883	0.588
1950	2.464	0.886	0.590
1955	2.200	0.837	0.558
1960	2.193	0.836	0.557
1965	2.253	0.847	0.565
1970	2.651	0.919	0.613
1975	3.048	0.985	0.656
1980	3.113	0.995	0.663
1985	2.582	0.907	0.604
1990	2.834	0.950	0.633

Figure 7.  
Actual and Calculated Travel Distances



The earlier study indicates that during the period from 1940 to 1990, the location patterns of Seattle supermarkets evolved in four stages (Yim, 1990). These stages were called previously stable random clusters, stable uniform clusters, unstable random pairs, and stable uniform singles. Stages of development characterized by travel distances in North Seattle were analyzed separately from the point map studies shown in the previous study. As it turns out they yield similar results. The stages of development characterized by travel distance measures were labeled as: 1) stable under high competition from 1940 through 1955, 2) stable under moderate competition from 1955 through 1965, 3) zone of change (unstable) from 1965 through 1985, and 4) stable under oligopoly from 1985 to

1990. Travel distance is market size related and market size is presumed to be determined by spatial competition. In the early stage of development, many independent firms created a highly competitive market. The higher the competition the smaller the size of each market and, consequently, the shorter the distance that consumers had to travel. However, as shown in Figure 7 the trend is now moving toward one supplier dominating the market. In Seattle, this supplier is Safeway.

#### **4. Rate of Change in Store Locations**

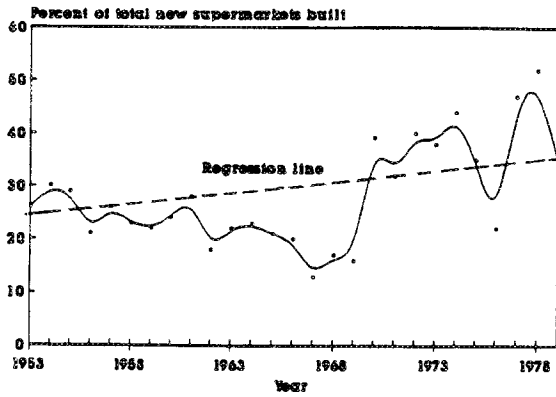
Attention is now directed to the rate of change in store locations. That is, how frequently have supermarket locations changed in Seattle over the past 50 years and what are the factors influencing the location choice of grocery stores? The rate of change in store locations is measured in two ways: the longevity of store locations and the survival rate of stores. This analysis is toward understanding the extent to which the travel patterns of food shopping are affected by the survival rate of food stores and the longevity of store locations.

##### **4.1. Overview of food retail locations**

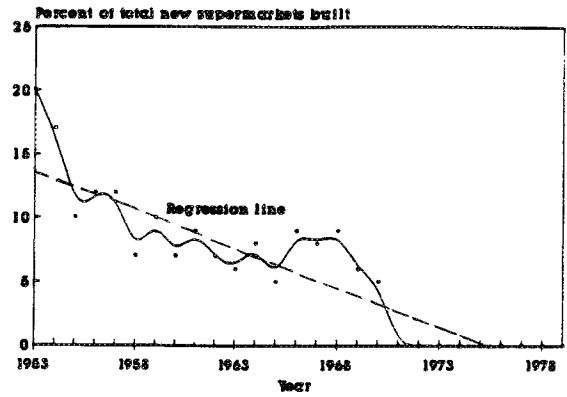
Supermarket sites are generally chosen from one of five alternative locations: old business centers, large shopping centers, small community shopping centers, neighborhood commercial districts, or freestanding locations near highway access points (Supermarket Institute, Inc. annual report series). Supermarket location trends are shown in Figure 8 through 12. During the 1920s and 1930s, there was a high rate of growth in chain grocery stores. Chains and independent food retailers offered self-service supermarkets which began to emerge in both older and newer neighborhoods. These supermarkets were typically built in locations around central business districts or near commercial districts along radial routes. In the 1940s, because of World War II, there was a period of development stagnation with few new supermarkets being built. By the early 1950s, supermarkets became the major source for food shopping and the store size nearly doubled from 7,000 square feet to 13,500 square feet. As shown in Figures 8 through 12, greater supermarket concentration occurred in modern suburban shopping centers, both

small and large, than in neighborhood commercial districts, old business centers, or freestanding sites.

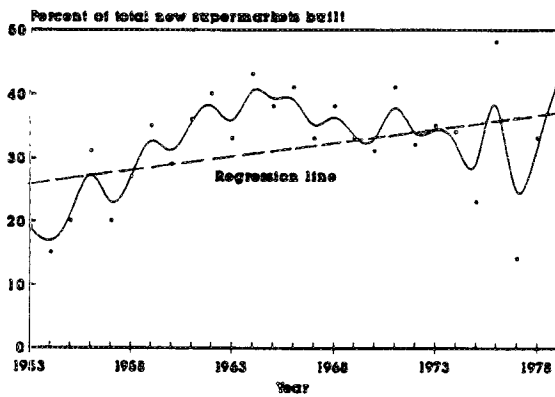
**Figure 8. Store Location  
Neighborhood Commercial Districts**



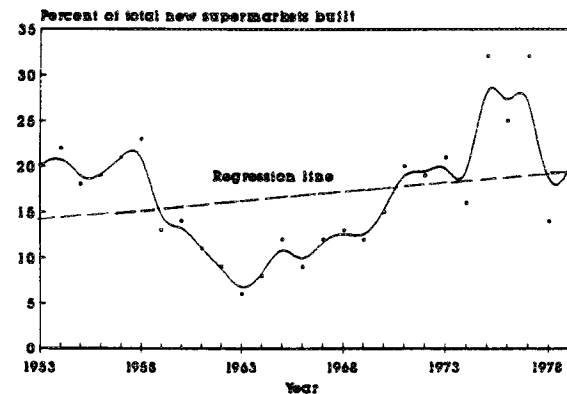
**Figure 11. Store Location  
Large Business Centers**



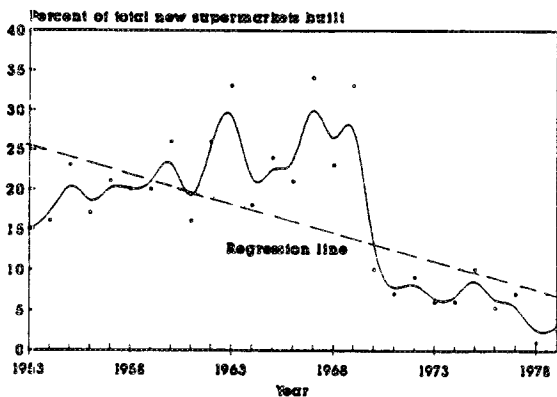
**Figure 9. Store Location  
New Small Shopping Centers**



**Figure 12. Store Location  
Freestanding Sites near Highway Access**



**Figure 10. Store Location  
New Large Shopping Centers**



During the 1960s, supermarkets became even larger, especially the ones in suburban communities. More than half of all new supermarkets (65%) were located in shopping centers. Small shopping centers gained a considerably higher number of supermarkets (40% of the new supermarkets built) than the large shopping centers (25%). The percent of new supermarkets built in neighborhood commercial districts remained the same but the percent of new supermarkets in old business centers and freestanding sites was significantly reduced.

The trend in the 1970s and 1980s was toward locating supermarkets in neighborhood commercial districts or small community shopping centers. Nearly 40% of new supermarkets chose neighborhood commercial districts and 35% chose small community shopping centers. Very few new supermarkets were built in old business centers or large shopping centers. Freestanding sites, however, became popular, mainly because of the availability of land.

In the 1990s, the trend to larger stores may continue along two basic paths. One is toward even larger supermarkets or superstores typically located in community-scale shopping centers adjacent to large drug and variety stores. The other path is toward ultra-large bulk discount stores (the warehouse type) developing in suburban areas around central cities. These bulk stores are currently locating on major urban arterials or near freeway access points serving regional scale markets. Only a few of these extra large stores are needed to serve an entire metropolitan area.

If bulk discounters continue to expand their share of the market, the conventional supermarkets will have to change. Since conventional supermarkets cannot compete in price, they will have to compete in other areas such as service and convenience -- qualities the bulk discounters have difficulty offering. Supermarkets may become more like large 'convenience' markets as they expand their ready-to-eat deli bars and exotic foods departments, acknowledging that the bulk discounters are taking away portions of their market share (Progressive Grocer, 1989).

#### **4.2. Choice of store locations**

As Nelson (1958) and Applebaum (1968) noted, retail business locations are all market oriented, and they are thus governed by accessibility to customers. Nelson and

Applebaum's studies of supermarket locations indicated that food markets are "generative" types. This means that store locations are strongly governed by the location of residential neighborhoods and that they provide goods and services that attract consumers. Grocers rarely make location decisions based solely on the "susceptible" type market attraction. Susceptible type shopping occurs when customers are "impulsively or coincidentally attracted while moving about the area where the retail store is located." (Applebaum, 1968.)

As Applebaum also noted, the value of a store location depends on three factors: 1) accessibility to residences and to people moving about, 2) physical attributes, including ample parking and safe environment, and 3) good will or store reputation. Nelson (1958) stated, "Each retailer chooses store location based on the productivity of the location relating to its potential ability to yield maximum profit." He suggested that food retailers must be aware of the following critical points in store location:

- 1) The market potential of the store location based on the sales volume and capture rate of the existing and future market in order to determine the risk factors of success, for example, whether food stores are over- or under-supplied prior to entering the market.
- 2) The market area's growth potential in terms of the consumer population. This is more applicable to the expanding suburbs than to the already built-up urban neighborhoods.
- 3) The physical accessibility to a trade area for self-sufficiency and for support from other neighboring businesses. The latter assists in extending a store's drawing power beyond the local trade area. It is better for food stores to be located with complementary stores than with similar ones.
- 4) The business intercept by locating stores between residences and the existing stores where people regularly shop for their groceries. In the same vein, retailers should avoid sites vulnerable to business intercept. Food stores, however, do not only compete with their locations but also with their prices and the quality of their service.

Retail experts regard the turn-over rate in supermarket locations as extremely high compared to comparison goods stores.

### 4.3. Distribution of supermarkets, chains vs independent stores

The analyses to be reported now are tests of a series of hypotheses with respect to the life cycle of supermarkets in Seattle. Our conjecture is that between stores and markets, balance is established by way of spatial competition. The null hypothesis, in a broad sense, is that changes in store locations are simply a result of birth and death processes that are driven by the random chance events of success and failure in a competitive market. The motivation behind the investigation of this hypothesis is to shed light on what seems to be the actual processes that take place in balancing store size and market size in competition. This section, therefore, examines whether the number of stores entering or leaving the market have proportional relationships to 1) existing supermarket populations or 2) the number of births or deaths of supermarkets at any given time.

Table 2 shows the opening and closing of supermarkets and the number of supermarkets serving North Seattle. There are ten observations; each five year interval is counted as one observation.

**Table 2. Number of Supermarkets Opened and Closed  
Frequency distribution - North Seattle**

Year	Stores Opened			Stores Survived			Stores Closed			Store Population		Total
	Chains	Independ	Subtotal	Chains	Independ	Subtotal	Chains	Independ	Subtotal	Chains	Independ	
1940										84	28	112
1945	7	14	21	49	15	64	35	13	48	56	29	85
1950	12	32	44	31	9	40	25	20	45	43	41	84
1955	19	22	41	16	15	31	27	26	53	35	37	72
1960	15	11	26	19	18	37	16	19	35	34	29	63
1965	8	9	17	32	19	51	2	10	12	40	28	68
1970	11	2	13	23	14	37	17	14	31	34	16	50
1975	3	0	3	22	9	31	12	7	19	25	9	34
1980	9	2	11	15	7	22	10	2	12	24	9	33
1985	3	0	3	24	4	28	0	5	5	27	4	31
1990	7	2	9	11	2	13	16	2	18	18	4	22
TOTAL n	(94)	(94)	(188)	(242)	(112)	(354)	(160)	(118)	(278)	(336)	(206)	(542)



The specific null hypotheses examined are:

- 1) Number of stores opened is proportional to the number of stores in the market.
- 2) Number of stores opened is proportional to the number of stores closed.
- 3) Number of stores closed is proportional to the total number of stores in the market.
- 4) Number of chain stores opened is proportional to the total number of new stores opened.
- 5) Number of chain stores opened is proportional to the number of independent stores closed.

To explain the method used in investigating the above hypotheses the steps followed in testing Hypothesis 1 are illustrated below.

**Step 1.**

Estimate the probability of the birth of a supermarket in time  $t_i$  in proportion to the total number of supermarkets in time  $t_i$ :

$$\pi_i = \frac{m_i}{\sum_{i=1}^{10} m_i}$$

$$\pi_i = \frac{m_i}{\sum_{i=1}^{10} m_i} = \frac{85}{542} = 0.1568$$

$$n_i = \sum_{i=1}^{10} O_i = 188$$

- $\pi_i$  = probability of stores being born in time  $i$
- $n_i$  = birth of stores in time  $i$
- $m_i$  = all stores in time  $i$
- $O_i$  = observed frequency of stores being born in time  $i$

**Step 2.**

Estimate the expected frequency in  $t_i$ :

$$E_i = n_i \pi_i$$

$$E_1 = 188 (0.1568) = 29.483$$

**Step 3.**

Compute the observed measure of deviation  $X_i^2$ :

$$X_i^2 = \sum_{i=1}^{10} \frac{(O_i - E_i)^2}{E_i}$$

$$X_1^2 = \frac{(21 - 29.483)^2}{29.483} = 2.441$$

The test shows that the observed data are, in general, not in agreement with our hypotheses. In Hypotheses 1, 2, 3, and 5, Chi-square values are relatively large, and P-values are very small, indicating that the observed frequencies have a large deviation from the expected frequencies (our hypotheses). Therefore, these hypotheses are rejected (5% significance level). However, Hypothesis 4 is not rejected (Table 3). Hypothesis 4 suggests that births of chain stores have proportional relationships to the births of all stores.

**Table 3. Null Hypothesis 4  
Chi-square Test Result**

Number of chain stores opened is proportional to the total number of stores opened.  
P-value is approximately 7. This hypothesis is not rejected (5% significance level).

**Chi-Square Goodness-of-Fit Test**

Observed Frequency	Expected Frequency	Chi-Square
7	10.5	1.1667
12	22.0	4.5455
19	20.5	.1098
15	13.0	.3077
8	8.5	.0294
11	6.5	3.1154
3	1.5	1.5000
9	5.5	2.2273
3	1.5	1.5000
7	4.5	1.3889

Chi-square = 15.8905 with 9 d.f.  
Sig. level = 0.0692032

From this analysis the following observations are made:

1) Considering long-run effects, the hypotheses of the proportional relationships generally do not hold. Food stores entering the market do not necessarily depend on the number of competing stores in the market. This suggests that the relationship is more complex than postulated. A possible reason for this is that the decision to enter the market is governed by many factors beyond spatial competition. Among these factors are changes in the local and national economies and disposable income. As shown in Table 2, the local economy is strongly reflected in the number of stores opened and closed in the post-war era as well as during the Seattle recession in the early 1970s when Boeing had a massive layoff. Between 1950 and 1960, the number of new stores opened averaged about forty stores per year. Stores closed during that time were about the same number. In 1975, there were only three stores opened but twelve stores closed.

Another factor, the life-cycle of stores, is significantly influenced by the emergence of modernized supermarkets and the high rate of growth in store size. Introduction of new types of grocery stores caused the stores to either expand on existing sites or to find new locations for large store sites. The high turn-over rate in supermarket locations could have been due to the replacement of many small old supermarkets with a few large modern superstores.

2) It is reasonable to assume that chain supermarkets enter a market in proportion to the total supermarkets opened. Any deviation shown between the observed frequency and the expected frequency is due to chance. Thus, the supermarket population may have been influenced largely by the behavior of chain stores.

3) Chain stores have increasingly dominated the market. The investigation of Hypothesis 5, that the opening of chain stores is proportional to the closing of independent stores, supports this observation. Although a fair number of chain stores were closed over the years, it appears that chains are taking over the entire food market in Seattle. See Table 2, the column showing the total store population.

#### 4.4. Survival times and longevity of store locations

This section addresses several questions related to store location patterns: to what extent are patterns of store locations dependent on historical paths? If location choices were made differently along the way, would the patterns have developed differently? Such questions are typically raised in industrial location and logistics literature. An example is the recent study by Arthur (1988) who asked, "could different 'chance events' in history have created a different formation of urban centers than the one that exists today," or do "the patterns of industry location follow paths that depend on history"? In his view, spatial patterns of industry locations are determined by "a mixture of economic determinism and historical chance -- and not [by] either alone." Patterns of urban activities cannot be explained or predicted without knowing what historical events have occurred. Arthur defines these as chance events, coincidences, and circumstances. It seems likely that patterns of store locations are also determined by both historical chance and economic determinants.

Within this context two aspects of store locations are examined from a historical perspective. One is survival times of supermarkets with respect to ownership, chains versus independent stores. The second is survival times of supermarkets with respect to the characteristics of store sites, old sites versus new sites. Old sites are defined as sites previously used for food retailing or sites that are within approximately a one block radius thereof. New sites are defined as locations where food stores are freestanding and where no food retailing has existed previously.

##### 1) Survival Time of Food Stores

The longevity of food stores in Seattle will now be discussed in terms of ownership, chains versus independents. What is the expected life-span of food stores in general and are chains able to survive longer than independent stores? The purpose of this investigation is to identify the length of time that stores survived during the study period from 1945 through 1985. Survival time is defined as the time from initial observation until failure. Failure is defined as the store's permanent closure.

For this analysis, survival time is grouped into five year fixed intervals. The

survivor function  $S(t)$  is defined as the probability that stores survived up to each fixed time increment, where  $t_0 < t_1 < t_2 < t_3 \dots < t_i$  and  $t = 5, 10, 15, 20, 25, 30, 35$  where  $t_1$  to  $t_6 = 35$  years.<sup>1</sup> In estimating probabilities of survival times, it is assumed that the probability of survival to time  $t_i$  is conditional on the survival to time  $t_{i-1}$ . In other words, survival of ten years,  $S(t_2)$ , depends on the success of the store operating for five years,  $S(t_1)$ . Since we have ten periods of data, probabilities of survival are given by:<sup>2</sup>

$$p(\text{survive} \geq 5 \text{ yrs}) = \frac{\sum_{i=1}^9 m_{i, i+1}}{\sum_{i=1}^9 N_i} = 0.576 \quad p(\text{survive} \geq 10 \text{ yrs}) = \frac{\sum_{i=1}^8 m_{i, i+2}}{\sum_{i=1}^8 N_i} = 0.296$$

$$p(\text{survive} \geq 15 \text{ yrs}) = \frac{\sum_{i=1}^7 m_{i, i+3}}{\sum_{i=1}^7 N_i} = 0.108 \quad p(\text{survive} \geq 20 \text{ yrs}) = \frac{\sum_{i=1}^6 m_{i, i+4}}{\sum_{i=1}^6 N_i} = 0.065$$

$$p(\text{survive} \geq 25 \text{ yrs}) = \frac{\sum_{i=1}^5 m_{i, i+5}}{\sum_{i=1}^5 N_i} = 0.035 \quad p(\text{survive} \geq 30 \text{ yrs}) = \frac{\sum_{i=1}^4 m_{i, i+6}}{\sum_{i=1}^4 N_i} = 0.016$$

$$p(\text{survive} \geq 35 \text{ yrs}) = \frac{\sum_{i=1}^3 m_{i, i+7}}{\sum_{i=1}^3 N_i} = 0.010$$

$N_i$  = new stores in period  $i$   
 $m_{i,j}$  = stores alive in period  $j$  that were born in period  $i$   
 $S(t)$  =  $p$  (survive  $\geq t$  years)

---

<sup>1</sup>Elston (1986) defines, "S(t) is also known as the cumulative survival rate, and the graph of S(t) is called the survival curve. At any given time t, S(t) gives the proportion still surviving at time t. .... Areas under this curve represent the probability of failure in intervals of time."

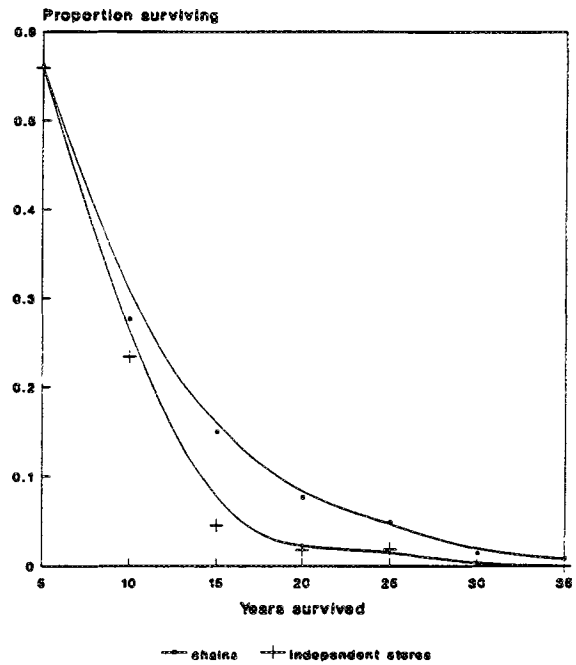
<sup>2</sup>The probability of survival is estimated by interpreting frequency of occurrences.

The above analysis indicates that the food store survival span is relatively short; just under one half of the 293 supermarkets observed during the study period failed within five years. This low rate of survival applied to both chains and independent stores in the short term, even though chains had a tendency to survive slightly longer in the long-run. Comparison of proportions survived between chains and independent stores is shown in Figure 13 and Table 4.

**Table 4. Survival Time  
Chains vs Independent Stores  
North Seattle**

Years	Chains	Independ
5	0.56069	0.55856
10	0.27647	0.23423
15	0.14900	0.04580
20	0.07595	0.01835
25	0.04762	0.01869
30	0.01439	0.00000
35	0.00800	0.00000

**Figure 13. Survival Curve  
Chains vs Independent Stores  
North Seattle**



The survival among all stores is exponential; therefore, the proportion surviving ( $Y_{all}$ ) among all stores is:

$$Y_{all} = 1.044e^{bx} \quad \text{Where } b = -0.136,$$

The rate of change in proportion surviving among all stores is:<sup>3</sup>

$$Y_{all} = (e^{a+bx})b$$

<sup>3</sup>In this equation and in the subsequent equations, we presented empirical estimates both in constant and exponential terms even though the boundary conditions required that a is equal to unity where  $Y = ae^{bx}$ . Our equations are valid only when  $x = 5$  years.

The changes in proportion surviving ( $\Delta Y_n$ ) after n years since year x is:

$$\begin{aligned}\Delta Y_n &= ae^{bx} - ae^{b(x+n)} \\ &= ae^{bx}(1-a^{bn})\end{aligned}$$

Where  $ae^{bx}$  is the number of beginning stores in time x,  $ae^{b(x+n)}$  is the number of stores remaining after n years since time x, and  $(1-a^{bn})$  is the percent of remaining stores lost in n year. The survival curves among chains and independent stores are also exponential. The proportion surviving ( $Y_{chain}$ ) among chains is:

$$Y_{chain} = 0.922e^{bx} \quad \text{Where } b = -0.082$$

The proportion surviving ( $Y_{ind}$ ) among independent stores is:

$$Y_{ind} = 0.855e^{bx} \quad \text{Where } b = -0.277$$

The high values of  $R^2$  indicate that exponential models fit food store survival curves very well.

## 2) Success and Failure of Store Locations

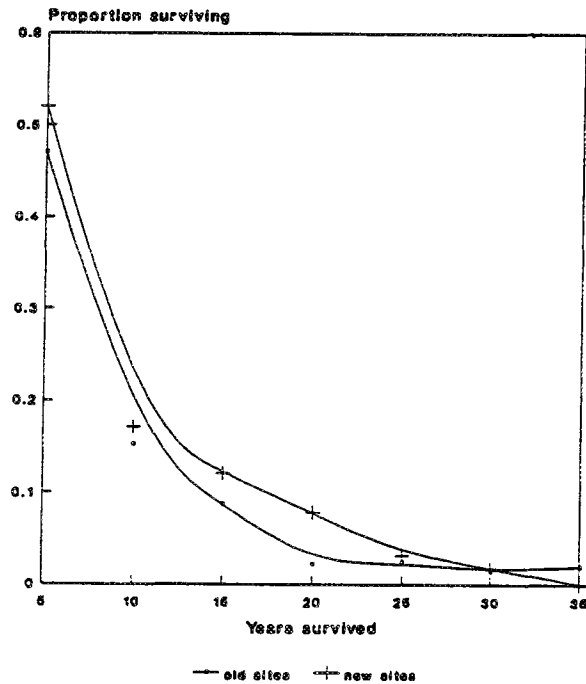
This section reports on the analysis of the survival times of store locations between old sites and new freestanding sites. The questions are: do stores choosing old sites have a higher success rate than those choosing freestanding sites and how frequently do stores seek new freestanding sites?

The analysis indicates that stores choosing freestanding sites have a slightly higher probability of surviving longer than the stores choosing old sites. The analysis shows that 52% of new store sites and 47% of old store sites are expected to survive more than five years. Seventeen percent of new store sites and 15% of old sites are expected to survive more than ten years. Comparison of the proportion of successes to failures among the old and new sites is shown in Figure 14 and Table 5.

Figure 14. Survival Curve  
Old Sites vs New Sites  
North Seattle

Table 5. Survival Time  
Old Sites vs New Sites  
North Seattle

Years	OldSites	NewSites
5	0.47000	0.52000
10	0.15150	0.17140
15	0.08696	0.12121
20	0.02198	0.07813
25	0.02500	0.03226
30	0.01400	0.01812
35	0.02000	0.00000



The survival curves of old sites and new sites are exponential. The proportion surviving ( $Y_{old}$ ) among old sites is:

$$Y_{old} = 0.839e^{bx} \quad \text{Where } b = -0.103$$

The proportion surviving ( $Y_{new}$ ) among new sites is:

$$Y_{new} = 0.883e^{bx} \quad \text{Where } b = -0.235$$

The short survival experience of food store locations implies that food shopping travel requirements change frequently. In about five years one-half of the stores change their locations, and food shopping traffic may alter accordingly. In ten years, nearly 70% of stores may seek new locations, and within fifteen years there may be a complete turnover in food store locations. By then it is likely that most consumers will be shopping at



different store locations which will undoubtedly create new travel patterns for food shopping.

## **5. Summary and Conclusions**

From this study, several conclusions can be reached: first, the total floor space of food stores is strongly correlated to market size measured in sales volume when the data aggregated at the state level are examined. Second, for many years, the actual average travel distances in Seattle to and from supermarkets were shorter than the transportation distances calculated under the optimal size of market. However, the actual average travel distance and the calculated average distance converged around the mid-1980s which indicates that an equilibrium was reached at that point. This convergence suggests that current food stores are located optimally. Third, using the travel distance measure, the study found that there were four distinctively different grocery shopping travel patterns in Seattle over the past 50 years. This finding concurs with the earlier study done with the location patterns of supermarkets in Seattle (Yim, 1990).

Fourth, spatial competition was presumed to be a benchmark for the measure of store location behavior, that is the movement toward a spatial equilibrium. However, a series of hypotheses tested indicates that the choice of a store entering the market is governed by factors other than spatial competition. These factors include the state of the local economy and the introduction of new store types. As mentioned earlier, food stores have evolved from superettes to superstores over the past several decades. This transformation process required ever-increasing store size and, as a result, there was a high turnover in food store locations.

Finally, the life span of supermarkets in Seattle was fairly short compared to other types of urban activities. Nearly 50% of the supermarkets failed within five years and over 80% failed within ten years. This rate applied to both chains and independent stores. Stores on freestanding sites showed a slightly higher probability of surviving longer than stores on old sites. The short survival span in store locations suggests that grocery shopping travel patterns may be altered significantly in the future.

The merit of this research lies in its approach toward an understanding of urban systems, the process of change with respect to scale and scope, location, life cycle,

mutation, and environment. In other words, this research was aimed at expanding our knowledge of the evolutionary process of urban activities as it relates to transportation requirements. In this study our research was restricted to transportation and retail activities. On a broad spectrum, a research topic deserving attention is the cumulative effects of transportation services on the entire food sector, including truck and rail transportation impacts on the productivity of the retail and wholesale food markets. For example, employment in farming, forestry, and fishing declined from 4.7% in 1972 to 3.1% in 1986 while technical, sales, and administrative support gained from 28.8% in 1972 to 31.3% in 1986 respectively (Congress of the United States, Office of Technology Assessment, 1988). The question is how does the whole span of transportation technology affect the shifts in the employment sectors of the food industry? There are also improvements to be made in the methodological aspects of this paper. For example, we used Euclidian distance in measuring travel distances to and from stores. This may not matter if only changes in relative travel distance are measured, but if quantitative measures of traffic diversions on networks are to be obtained, the block distance measurements would be more useful.

The findings of the study suggest that the relation of transportation services to retail activities is not a straightforward one. It is a complex relationship and involves the evolution of technology. Changes in technology regimes provide opportunities for innovation in production and marketing. This neo-Schumpeterian view of the process of change makes urban systems complex and difficult to model (Nelson and Winter, 1982). As a result, this paper opens up many puzzles. Further studies in this general area will provide opportunities to obtain deeper understanding of the relationship of transportation to the behavior of urban retail activities.

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