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The impact of multi-stop, multi-purpose shopping on the location and efficiency of a supermarket chain: A location-allocation approach

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THE IMPACT OF MULTI-STOP, MULTI-PURPOSE SHOPPING ON THE LOCATION AND EFFICIENCY OF A SUPERMARKET CHAIN: A LOCATION-ALLOCATION APPROACH

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Abstract

As the retail environment became increasingly competitive and the risks of opening new outlets also increased, there became a need for firms to develop a quantifiable location strategy in order to help them minimize these risks and be successful in the market place. Past location models however, modeled consumer shopping trips as consisting of a single-stop, single-purpose, were home generated and were only considered with the impact of a single store location. Recent literature however, has revealed consumer shopping trips as being more complex with multiple stops and multiple purposes. In addit on, the retail environment has shifted from consisting of mainly independent retailers to one comprised of mainly retail chains. Subsequently, what has emerged is a need to incorporate this more complex set of consumer shopping trips into a location model which can optimally locate an entire network of stores. It is this need which forms the basis of this study. The objective of this study is to vary the demand surface according to different combinations of single-stop, single-purpose and multi-stop, multi-purpose shopping trips and assess what impact these variations have in terms of the spatial location of outlets and the economic success of the firm. Each spatial demand pattern is incorporated into a p-median location-allocation model for outlets of a supermarket chain in Kitchener-Waterloo in 1981. It is shown that store locations tend to concentrate in the downtown as the level of multi-stop, multi-purpose trips increase. Also, areas which are highly sensitive to changes in demand patterns tend to be in the outlying areas while those which are insensitive tend to be in the downtowns. Furthermore, the solution which is optimal from the consumers' perspective is not the same for the retailer. As a result, this study analyses the extent of sensitivity of store locations to the movements of their consumers.

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Table of Contents

List of Figures

List of Tables

CHAPTER ONE

INTRODUCTION AND OUTLINE

1.1 Introduction

There has always been a need to understand the spatial arrangement of various activities in our environment. One aspect of our environment which has sparked a curiosity among both the academic and the private sectors is the commercial structure or retailing environment. One reason for this is that the retail environment has undergone significant changes in the past 30 to 40 years resulting in the general shifting spatial pattern of the commercial spatial structure. More specifically, where retail outlets were once confined to localized neighbourhoods consisting of largely independent retailers, the suburbanization of Canada's metropolitan areas resulted in a decentralized pattern of outlets. Lifestyle changes and other complex factors have also produced a smaller, yet prominent trend towards the re-urbanization of the downtown areas. These changes in the commercial spatial structure are mainly attributable to more specific changes in retail composition and organization as well as changes in consumer behaviour.

It is the result of these various changes in the retail environment in terms of its composition and organization as well as the behaviour of its consumers which has attracted the interest of researchers. These changes, (which will be discussed in more detail in Chapter 2) and their interrelatedness have created a complex environment in terms of both the spatial location of outlets as well as the shopping behaviour of consumers. It is this resulting complexity in the shopping behaviour of consumers that has been the focus of recent literature. For instance, in the past, shopping trips were generally simple as they originated from the home with the only stop being the destination or place of purchase (O'Kelly 1983a). In this case consumers' shopping trips consisted of one stop (the place of purchase) and one purpose (to shop). This type of shopping trip became known as the single-stop, single-purpose trip. This type of trip was largely a result of the low female participation rate in the labour force. Consequently, researchers simulated this type of shopping trip by an origin-destination-origin flow with the origin being the place of residence and the destination the place of purchase.

Due to changes in the employment structure, lifestyles and the economy etc., shopping trips are no longer that simple. Shopping trips have become more complex by consisting of multiple stops and/or multiple purposes. For example, the onset of planned shopping centres which house a variety of shopping opportunities and services have provided the opportunity for the consumer to engage in shopping trips consisting of a single stop but multiple purposes. Also, increased accessibility due to increases in car ownership and the availability of public transportation have made it easier for the consumer to comparison shop on the same shopping trip. This type of shopping trip constitutes a single purpose, multi-stop trip. The most complex shopping trip consumers engage in is one which consists of multiple stops and multiple purposes. For instance, shopping trips presently are often found to originate from places other than home such as, places of employment, recreation etc. This has produced trips which, although originating from home, consist of more than one stop before the actual place of purchase. As a result, this type of shopping trip is comprised of at least two stops (work, recreation etc. and the place of purchase) and two purposes (work, recreational activity etc. and shopping).

The realization by researchers of the importance of the multi-stop, multi-purpose shopping trip has led to the continued focus on methods to accurately model this type of complex consumer shopping behaviour and to assess what impact it may have on both the commercial spatial structure and the location strategy of retailers.

It is also out of this complexity that the importance of a good location strategy as a part of a retailer's overall marketing strategy has emerged. These changes that have occurred in the retail environment have produced a highly competitive environment in which retaining and capturing new markets becomes more difficult. This problem has become even more pronounced in the last decade as real estate and development costs have increased. As a result, this has lead to the emergence of various techniques, ranging from the very simple to the very sophisticated, to aid in the location decision by the retailer.

1.2 Objective of Study

It is the emergence of these two trends, the increase in the complexity of consumer shopping behaviour in the form of the multi-stop, multi-purpose trips and the need to quantify the location strategy of the firm which will form the basis for this thesis. The realization by researchers of the predominance of the multi-stop, multi-purpose trip has generated a need to understand the effects this type of shopping behaviour will have. More specifically, having consumers shop from locations other than home will create a very different spatial pattern of consumer demand. The question that arises from this is what effect these different patterns of demand will have on the locational strategy of the retailer and on the commercial spatial structure. As a result, the overall objective of this thesis is to determine the extent to which these variations in the spatial demand patterns (reflecting different combinations of single-stop, single-purpose and multi-stop, multi-purpose trips) will have on the locational strategy of the firm in terms of the spatial locations of outlets and the economic success of the firm. In terms of this particular study, these different spatial demand patterns will be incorporated into a P-median location-allocation model for the outlets of a supermarket chain in Kitchener-

Waterloo in 1981.

The importance of this study is that it will reveal to what extent changes in consumer shopping patterns can effect store location. If store locations are effected by the shopping patterns of their consumers, this will emphasize the importance of a retailer having an effective location strategy. Effective in the sense that it will incorporate detailed knowledge of the locations and purchasing patterns of a firm's present and future target markets.

1.3 Outline of study

The following chapters in this study consist of four main sections. The purpose of Chapter Two is to reveal the important factors that form the rationale behind the objectives of this study and the general methodological approach to be taken. Chapter Three will be mainly comprised of a more detailed description of the research problem as it pertains to this specific study as well as a detailed outline of the methodological approaches to be used in both the generation of the results and their subsequent analysis. The fourth and fifth chapters consist of the description and discussion of these results respectively.

CHAPTER TWO

REVIEW OF EXISTING LITERATURE

Canada's retail environment has undergone significant changes since World War II largely as a result of two important factors; changes in retail organization (or ownership structure) and composition (types of stores) and changes in consumer behaviour. The purpose of this chapter is to describe these changes in more detail and to reveal how the impacts of these changes have led to two trends; the development of the multi-stop, multi-purpose trip and the need for a quantifiable location strategy by the retailer. Preceding this will be an examination of the various methods of locational analysis most often used. Furthermore, it is the description of their uses and disadvantages that will provide the rationale behind this study's use of the location-allocation model. In addition, examining the past uses of the location-allocation model in retailing will reveal the uniqueness of this study within the existing literature in marketing geography.

2.1 Retail Composition and Organization

The changes in Canada's retail organization and composition have had a considerable effect on both the behaviour of consumers and the spatial location of commercial outlets. Up to approximately the 1950's, the composition of Canada's retail system was dominated by independent retailers. As suburbanization and car ownership increased, retailers expanded to the suburbs to take advantage of the suburbanization of their consumers. The type of retail outlet available to the consumer came in the form of a planned shopping centre. This provided consumers with more extensive shopping alternatives by providing a more conducive environment for an agglomeration of stores and services, thereby altering the spatial location of outlets. As a result, the locations of stores and their spatial concentrations provided the option of the multi-stop and multi-purpose trip in which consumers could minimize the cost and distance of their travel patterns. In this case a multi-stop trip will be looked upon as a trip consisting of more than one stop for either similar or dissimilar goods and activities and a multipurpose trip as a multi-stop trip in which consumers engage in activities of different types. The changes in consumer travel patterns and the spatial patterns of outlets together with their inter-relatedness has resulted in an even more complex environment for the retailer. This, in turn, gives rise to the need to understand the role these factors play in a firm's location strategy.

As a consequence of the growth of these planned shopping centres, resultant changes in the ownership structure in retailing also occurred (Jones and Simmons 1987). This increased growth in retailing saturated the commercial structure of the cities. Competition between firms grew, thereby increasing real estate costs, development costs etc. making the opening of a business a costly venture. These increased costs and competition provided the proper environment for the growth of the retail chain which could take advantage of economies of scale such as reduced average cost of administration, advertising and distribution etc. This would increase the firm's visibility to consumers, and consequently altering their shopping behaviour thereby increasing the chain's chances of success and potential for growth. For instance, in 1979 Canada had 694 chains (Simmons, 1989, pg.6) but by 1983 there were 29,000 stores controlled by 1,100 chains accounting for greater than 40% of all retail sales (Jones and Simmons, 1987, p. 70). These changes in retail ownership have not only increased the level of competition between the independent retailers and the chains but also amongst the chains themselves. The needs, preferences and locations of their present and future potential markets became a necessity because the greater mobility of consumers. This increased mobility gave consumers a wider range of products and store locations to choose from. It is quite possible that this may effect the locations of retail outlets and their need for an effective location strategy.

2.2 Changes in Consumer Behaviour

A second factor thought to affect the spatial location of retail outlets is that of changes in consumer travel behaviour. Initially, it was assumed that most consumers' shopping trips were to the nearest outlet, were single purpose, home generated and usually done by women (Simmons, 1989). Now however, travel patterns are no longer that simplistic. Some of the reasons for more complex behaviour have stemmed from changes in the country's employment structure as more women enter the work force. This increases the necessity of work-related shopping trips as well as an alteration in travel patterns. For instance, Davies (1984) found that in Britain over 1/4 of the working women undertake their major shopping trips from their work places rather than from home. Even as far back as the 1960's it was found that of the households visited in Littlehampton and Seaford, England, a significant proportion were engaging in work related trips (Ambrose 1968).

Another significant change that occurred which had a major impact on consumer travel behaviour was the increase in car ownership. This provided consumers with greater and easier access to shopping opportunities thereby expanding their choice of where to shop and increasing their ability for more frequent number of stops on the same trip. The changing consumer travel patterns which have resulted have led to the emergence of more complex consumer behaviour in the form of the multi-stop, multi-purpose trip.

Interest has been generated into the extent to which these various types of travel patterns occur and are representative of actual consumer behaviour, as well as their subsequent affect on the spatial locations of firms. In terms of the importance of these types of travel patterns, much literature has evolved out of the need to assess ways of testing the validity of the nearest-centre approach to multi-stop, multi-purpose travel patterns in describing actual consumer behaviour. Differences in travel behaviour have been found in a world-wide context as well as an intra-urban one. For instance, it has been found that in developing countries consumers travel patterns are better represented by the nearest centre, single purpose hypothesis while in the western world this hypothesis, has a more limited applicability (Hubbard 1978).

The literature on the intra-urban scale has assessed not only the extent of different types of travel behaviour but also the variability of their importance according to the type of good to be purchased. For instance, O'Kelly (1983a) compared models of single-stop, single-purpose trips and multi-stop, multi-purpose trips to actual travel patterns for grocery and nongrocery purchases. He found that overall, the model incorporating the multi-stop, multi-purpose trips provided a better fit to actual patterns and was more stable. More specifically however, the patterns of grocery shopping revealed the prevalence of the nearest centre allocation rule while nongrocery purchase patterns showed a greater flexibility in destination choice. Similarly, Ambrose (1968) found that, although the relationship between trip frequencies and distance travelled varied between different types of shopping, over 1/3 of all purchases were made at points beyond the nearest outlet in conjunction with other types of trips. Consequently, it becomes evident that while the emergence of models incorporating multi-stop and multi-purpose trips to represent consumers travel behaviour is a truer reflection of actual travel behaviour, the extent to which it is important is heavily influenced by the type of good bought.

This prevalence of multi-stop, multi-purpose trips has in turn affected the spatial environment and vice-versa and realizing this could have implications for retailers in the future. For instance, Ghosh and McLafferty (1986) assessed the impact various levels of multi-purpose shopping have on the spatial competition among firms. They found that high levels of multi-purpose shopping tended to make firms agglomerate while low levels led to a more dispersed locational configuration of outlets. Similarly, Hanson (1980) looked at the effect of multi-purpose travel on retail choice and found that not only did the frequency of travel vary by purpose but there was little overlap between destinations visited on multi-purpose trips and single-purpose trips. Both studies reveal the importance of firms understanding the travel behaviour of their consumers.

On the other hand however, the locational configuration does in fact alter the travel behaviour of consumers. More specifically, Ghosh and McLafferty (1984) found that the optimal propensity for multi-purpose shopping and trip frequencies vary with the consumers' location in relation to shopping opportunities. In addition, O'Kelly (1981), using a conditional probability model to find the level of demand for facilities in the presence of multi-stop, multi-purpose trips, found that central locations have the highest level while suburban locations have lower levels.

Overall, it should be evident that it is necessary to understand this complex environment created by the interrelationship between travel behaviour and the location of retail firms in order to determine the importance of location strategy in a firm's overall marketing strategy.

2.3 Existing Methods of Site Selection and Location Analysis

In response to this growing interest into consumer behaviour and the realization of the importance of a good location strategy various mathematical models have evolved to predict and assess the impacts of a firm's location decision. There are six commonly used approaches to retail site selection ranging from the very simple to the very complex. Their use often depends on such factors as the objectives of the researcher or retailer, the availability of data and the amount of time and money the retailer wants to spend on the site selection process. These approaches are; rules of thumb, descriptive inventories, site rankings, regression models, spatial interaction models and location-allocation procedures.

2.3.1 Rules of Thumb

In this approach, the researcher uses a key factor felt to be directly related to sales performance based upon previous experience or some sort of empirical observation. The researcher then uses this as the location criterion on which to screen potential locations. The advantages of this method are that it is inexpensive, quick and simple. Its disadvantages are that it is overly simplified and extremely subjective. Consequently, its main use is by firms that are relatively insensitive to location and whose target market is not clearly fixed. (Jones and Simmons, 1987, p. 277-279)

2.3.2 Descriptive Inventories

This approach is somewhat of an extension of the previous method. Instead of one factor being identified, a list of key factors is developed to identify the most relevant location criteria for a particular chain. These factors are then used as the basis for evaluating and selecting store locations. Its main use is often as a preliminary stage to the more quantitative location methods. Its main disadvantage is that it does not and cannot make any attempt to assess the previous relationship between the level of sales of the outlet and the chosen key factors. As a result it is still subjective and also consists of the same shortcomings as the Rules of Thumb method. It is only really useful in assessing single sites thereby limiting its applicability as a general location model for multiple sites (Jones and Simmons, 1987, p.279).

2.3.3 Ranking

In this case a ranking scheme of the various factors thought to be important location criteria is developed by the retailer often accompanied by weighting of some of these factors. The ranking scheme is then applied to the various sites and those with the highest rankings are chosen. Although this approach allows the comparison of different sites, there is no evaluation of whether the factors in the ranking scheme are actually good indicators of sales performance. Consequently, this is really only a useful method for chains who are just beginning to evaluate sites and want a fairly simple, inexpensive and general method of site selection and evaluation (Jones and Simmons, 1987, p.280).

2.3.4 Regression Models

The main idea behind using regression models in the site selection process is that it is a way of making quantitative comparisons between the performance of existing outlets and the various key factors which then can be used to predict the level of sales at any new site. The general form of the regression model is:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots b_kX_k$$

In this example **Y** is the dependent variable (usually some measure of sales performance), $\mathbf{X_1 \ldots X_k}$ are the key factors and $\mathbf{b_1 \ldots b_k}$ are partial regression coefficients. By comparing the known performance of existing outlets with measures of the key factors, $\mathbf{b_0 \ldots b_k}$ are determined statistically. Subsequently, once the model is calibrated with real values for the regression coefficients, it can be applied to any new site for which the key factors are known. The results from the application of this model can be applied in evaluating the performance of existing sites as well as the potential for new ones.

This method is most successful when applied to a retail outlet selling low order convenience goods where the associated consumer behaviour is relatively simple. Although this method provides a means to contrast different retail environments by explicitly evaluating sales potential, it requires a large investment by the retailer in terms of the development of an extensive data base and in the calibration of the model, both of which must be continually updated and monitored. (Jones and Simmons, 1987, p. 287)

2.3.5 Spatial Interaction Models

One of the most common groups of models used in locational analysis is spatial interaction models. In general terms, the model takes the form of an equation which predicts the size and direction of some flow (the dependent variable) using independent variables which measure some structural property of the human spatial environment (Thomas and Huggett, 1980, p.132).

Spatial Interaction models in their original form were often referred to as gravity models because their mathematical assumptions are similar to those in Isaac Newton's law of gravitational attraction. The simplest model combines distance and variety concepts into a mathematical relationship (Jones and Simmons, 1987). The most basic gravity model predicts T_{ij}, the number of trips for household $_i$ to centre $_j$ (alternatively, the number of purchases by household $_i$ at centre $_j$) where;

$$T_{ij} = K \frac{a_j^{b_1}}{d_{ij}^{b_2}}$$

In this equation K, b_1 and b_2 are constants to be evaluated in specific situations usually by regression analysis. The constant b_2 is a measure of the consumer's sensitivity to distance d_{ij} between $_i$ and $_j$. The larger the value the greater the friction of distance. Similarly, $a_j^{b_1}$ measures the attractiveness of the centre. The parameter K scales the result according to some unit of measurement (eg dollars per household). Over time however, b_1 and b_2 change as the importance of distance and variety changes (Thomas and Huggett, 1980, p.135).

Subsequent models have been refined by trying to incorporate more complex consumer behaviour into the model which is exemplified in Reilly (1931) and Lakshmanan and Hanson (1965). Even though these models have tried to try to better reflect more realistic consumer behaviour, they are associated with some major disadvantages. Not including the more technical criticisms of spatial interaction models, conceptually, their disadvantage lies in their inability to consider an entire network of stores. This is important as Canada's retailing environment consists mainly of retail chains forming networks of retail outlets (Jones and Simmons, 1987).

Aside from the more specific disadvantages associated with each of these previously described methods of site selection, there exists one overall drawback which forms the basis of the model to be used in this study. More specifically, the most significant drawback of these models is that they cannot and do not assess the whole network of stores and the impacts of opening multiple units on the existing network (Craig, Ghosh, McLafferty, 1987). This is especially important since the retail chain (whose marketing strategy most often involves the simultaneous opening of multiple outlets in order to achieve greater market penetration) dominates the Canadian retail system. Hence, there is a need for a model to assess an entire network of stores.

2.4 The Location-Allocation Model

The only model to address this need is the location-allocation model. The overall concept of this model is that it simultaneously allocates a given spatial distribution of demand to a specified number of outlets (Jones and Simmons, 1987, p.292; Ghosh and McLafferty, 1987, p. 129) Most work incorporating the model, however, has centred on the planning of health care facilities, emergency facilities such as fire stations and other public services (Goodchild, 1984, pg. 84). There exists however, a huge potential for its use in retailing as it can be used to assess the efficiency of a network of stores and the benefits of adding new stores to existing networks (Jones and Simmons, 1987, p. 292). Despite this, its application to retailing has been minimal in comparison to its uses in the public sector.

The use of location-allocation models in retailing has touched upon five, somewhat interrelated areas; the addition and deletion of outlets, the development of a location strategy in uncertain environments, the use of spatial interaction models to try to incorporate more realistic consumer behaviour, the incorporation of multi-purpose shopping and the sensitivity to parameter manipulation. For instance, Goodchild (1984) used the model to find the optimal locational configuration for a third restaurant in accordance with its two existing locations. Ghosh and McLafferty (1982) calibrated the model using different possible future scenarios to determine the optimal locations of two new stores to a supermarket chain in the presence of competition.

In terms of an example for the deletion of stores in a network, Goodchild (1987) looked at the case of gasoline retailing in which the number of facilities was to decrease from 31 to 20. Two types of demand were used and their optimal locations compared. The first represented single-purpose shopping by residential allocation while the second used traffic volume to represent multi-purpose and impulse shopping. Although both solutions shared a number of common locations, this could be due to a strong correlation between the underlying spatial demand patterns.

The use of the model in uncertain environments is exemplified in Ghosh and Craig (1984 and 1983). In their 1984 study they developed a model to deal with site selection in a competitive environment by evaluating the desirability of multiple locations in terms of both existing and possible future locations. In their 1983 study they used a Multiplicative Competitive Interactive model (MCI model) which is a type of spatial choice model, to develop a location strategy for a firm taking into account future changes in the environment. For instance, in this specific application the MCI model was used to estimate market share and simulate the effects changes in store characteristics have on the performance of the various stores entering the market.

In order to represent a more complex environment, various authors have tried to incorporate spatial interaction models into the location-allocation model to try and reflect a more realistic method of determining the allocation of demand. For instance, Hodgson (1978) used an entropy maximizing interaction model rather than using a least-cost allocation rule. The entropy maximizing model he used is just another type of spatial interaction model in which the optimal solution is one which maximizes the individual's freedom to choose between all of the journey-to-work routes. (Thomas and Huggett, 1980, p.156.) In 1981 he incorporated a production constrained gravity model to allocate consumers to motor vehicle branches and compared this to the nearest centre results. The findings revealed that the locational results were not very different between the two models. Finally, O'Kelly (1987) incorporated a probabilistic allocation rule instead of one based on the nearest center approach into a continuous space location-allocation model. This probabilistic algorithm was then applied in a case study for Hamilton, Ontario which used a 181 by 181 travel time array for 181 zones. His objective was to locate 20 facilities under two different parameter conditions. More specifically, the parameter he varied was β which is a measure of the consumer's sensitivity to distance (see section 2.3.5). The first condition was with a small β value (.025) and the second condition with a β value of .2. He found that using a small parameter revealed a clustered set of activities with little or no preference for the nearest facility while a larger parameter was associated with a more dispersed set of locations with more marked preference for the nearest facility. This sensitivity of locations to a changing parameter reveals the importance of determining more accurate consumer travel behaviour.

The incorporation of spatial interaction models into a location-allocation model as a more realistic method of allocating consumers was attempted by various researchers. Results showed however, the resulting solutions were not that different from those obtained under the nearest center approach. O'Kelly also revealed the importance of determining an accurate β value in order to get an accurate solution. Subsequently, determining the appropriate β value then becomes a possible limitation of using probabilistic allocation rules. As a result, what is needed is a method to incorporate more realistic consumer behaviour which avoids some of the problems associated with spatial interaction based location-allocation models.

In terms of incorporating multi-purpose shopping behaviour, only one attempt has been made to try and incorporate this type of consumer behaviour into a location-allocation model. McLafferty and Ghosh (1987) tried to develop a location-allocation model to study the spatial organization of retail firms in a multi-trip environment. They determined (endogenously) the optimal propensity for single and multi-purpose shopping with different combinations of low and high order firms as well as the impact of changes in price and costs on the locational configuration of outlets. They found that the frequencies of single and multi-purpose trips depend on the consumers location relative to shopping opportunities.

Although the existing literature on using location-allocation models in retail scenarios is varied and sparse, it also has not effectively incorporated any of the existing literature on consumer behaviour. For instance, although Hodgson (1978 and 1981) tried to use spatial interaction models as representations of more realistic consumer behaviour, he did not explicitly try to incorporate the concept of the multi-stop and multi-purpose trip. Consequently, his study does not adequately reflect consumer behaviour and is only increasing the time and cost of calibrating the model (Goodchild 1984, pg. 96). Although Ghosh and Craig (1983 and 1984) tried to incorporate a more dynamic location scenario, they based all locations on home generated trips. Goodchild (1984) also used home generated trips and it is only in his 1987 study that he tried to reflect both types of trips. Finally, although McLafferty and Ghosh (1987) tried to incorporate the idea of multi-purpose shopping into a location-allocation model their model does not consider what impact this type of shopping will have on an existing network of stores, the commercial spatial structure and the implications that may arise for the retailer in terms of his firm's location strategy.

It is evident from reviewing this literature that minimal attempts have been made to try and link the concept of the multi-stop, multi-purpose trip with methods of locational analysis. For instance, no attempt has been made to model different types of consumer shopping trips on a large scale and incorporate them within a location-allocation model. As a result, no attempts have been made to assess the potential impact variations in types of shopping trips may have on the commercial spatial structure. Assessing this impact is essential as this could have major implications for both the retailer and the consumer. It is this present void in marketing geography and especially location-allocation literature, which not only forms the basis for this thesis but also reveals its uniqueness.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In order to be able to observe how changes in consumer shopping behaviour effect the spatial location of outlets produced from the location-allocation model as well as on the efficiency and success of the chain itself, certain methodological approaches need to be taken. Firstly, it is necessary to develop a more specific definition of both a single-stop, single purpose trip and a multi-stop, multi-purpose trip. Secondly, it is essential to discuss the type of data which will be used in this study and how it will be implemented to generate different spatial distributions of demand incorporating these two types of shopping trips. Thirdly, the criteria to help define the appropriate study area and retail chain in which to apply the objectives of this study are also needed. Fourthly, the choice of the appropriate location-allocation model which best reflects the objectives of the study is also essential. Lastly, after obtaining the various solutions under different distributions of demand (see section 3.3) it is necessary to determine the most effective method to assess how these changes in demand effect the spatial location of outlets as well as the impact on the efficiency and success of the entire network of outlets.

3.2 Defining the Two Types of Shopping Trips

The types of shopping trips consumers engage in fit into four main groups; single-stop, single-purpose; single-stop, multi-purpose; multi-stop, single-purpose and multi-stop, multi-purpose. This study is mainly concerned with the two extreme types of shopping trips, single-stop, single-purpose and multi-stop, multi-purpose. In order to model both types of shopping trips a more specific definition is required of each. The previous definition of a multi-stop, multi-purpose trip given in section 1.1 is too broad as it defines consumers as shopping from virtually anywhere except home. The problem that arises is how to model such complex consumer behaviour without knowing more about the underlying population. One thing that is known is that many shopping trips originate from places of employment. Shopping from work however, does fit into this study's more general concept of the multi-stop, multi-purpose trip described in section 1.1. This is because by shopping from work the consumer has engaged in two purposes (working and shopping) and two stops (home to work and work to the place of purchase). This is the simplest form of the multi-stop, multi-purpose trip as it consists of only two stops and two purposes. Subsequently, in this study multi-stop, multi-purpose trips are those in which consumers shop from their places of employment and thus, will also be referred to as work-based trips. Single-stop, single-purpose trips are defined as those which originate from the consumers' places of residence and have only one stop (the place of purchase) and one purpose (shopping).

An important assumption that results from defining shopping trips in this way is that if consumers are not shopping from their place of employment (work-based trips) they are shopping from their place of residence (residential-based trips). The importance of this assumption is that it makes it possible to model different combinations of work-based and residential-based trips by varying the proportion of each. For instance, by decreasing the proportion of work-based trips we are increasing the proportion of residential-based trips as those who are not shopping from work are reallocated back to their place of residence from which they will then shop. This will be described more fully in the next section.

3.3 Generation of the Spatial Distribution of Demand

As it was noted in Chapter One, what this study is doing is varying the spatial distribution of demand according to different combinations of work and residential-based shopping trips. The demand surface will be represented by the number of adults (customers) in a set of census tracts which cover the study area. The rationale behind considering only adults to represent consumer demand is essentially two fold; the first reason being that grocery shopping is usually done by the adults in the household and secondly, because there is no data indicating the level of demand each adult represents, as the locations of these adults change as they engage in different combinations of single-stop, single-purpose trips and multi-stop, multi-purpose shopping trips there is no way to correctly allocate the level of demand associated with each of them.

The location of these customers is considered to be the centroid of the census tracts. The reason for using the census tract centroid will be explained more fully in section 3.6.2. The level of demand at each census tract location is essentially produced by two types of demand. The first type of demand is a constant one which includes those consumers whose locations do not change. This is because they are either unemployed, work at home or work in the same census tract in which they live and hence, the locations from where they shop do not change as the type of shopping trip changes. The second type of demand is a variable one as it consists of those employed consumers whose residence and employment locations are not the same. Subsequently, the next step is to determine a method to obtain the level of demand associated with each census tract under different combinations of work and residential based trips.

The data which will be used in this study is the journey-to-work flow data from Statistics Canada for 1981 (Statistics Canada CTD81B31) (Appendix 1). This data shows for each census tract, the number of people who are coming to work there from outside the census tract in and outside the Census Metropolitan Area (CMA). It also provides information for each census tract on the number of people who work at home, and the number of people who don't work at home but who work in the same census tract. Data which will also be used is employment data showing the number of unemployed people for each census tract (Statistics Canada 1981, Catalogue 95-915). In order to be able to better use this data to determine the level of demand for each census tract it was necessary to put it into a more workable form (Table 1).

The advantage of setting this data up in a matrix is that it is possible to formulate an equation to determine the level of demand at each census tract in the study area according to different combinations of work and residential based shopping trips. As a result the level of demand, D_j for each census tract j, becomes:

$$D_j = N_j + H_j + KI + R_j + S_j$$

where : N_j: The number of people unemployed in census tract $_j$

H_j: The number of people who work at home in census tract $_j$

I: The number of inflow workers from other census tracts into census tract $_j$ where:

$$I = \sum_{\substack{i=1 \\ i \neq j}}^{n} f_{ij}$$

where: f_{ij} = the number of people living in zone $_i$ who work in zone $_j$

K: The level of multi-stop, multi-purpose shopping trips

R_j: The number of workers who live in $_j$ but work outside $_j$ who do not engage in multi-stop, multi-purpose trips who are re-allocated back to their place of residence

S_j: The number of people who work in the same census tract as they live

In this equation there are three constant values which do not change for any census tract; the number of people unemployed (N_j), the number of people who work at home (H_j) and the number of people who work in the same census tract as they live (S_j). These variables represent the constant demand mentioned at the beginning of this section. They are constant in the sense that in terms of the model, these consumers' will always preside in the same census tract as they live whether they are employed or not. Subsequently, their location will not change when varying work and residential based trips. As a result, the level of demand that they contribute will stay the same numerically and spatially no matter what combinations of shopping trips are chosen.

I, *K* and *R* are essentially the variables reflecting changes in consumer shopping trips and will alter the level of demand at the census tracts under the different combinations of work and residential based shopping trips. For example, for each demand node, *I* is the total number of workers who work in that census tract but reside outside of that census tract. Furthermore, *K* is the level of multi-stop, multi-purpose trips or in other words, the proportion of work based shopping trips. If everyone were to shop from work (100% multi-

Table 1

General Organization of Journey-to-Work Flow Data

Resident Zone (i)	Employment Zone (j)	Outside of Study Area	
	1 . . . j . . . n		
1			
.			
.			
.			
i	f_{ij}		f_{ij}:
.			The number of
.			people living in
.			zone i who work
n			in zone j
Outside of Study Area			

stop, multi-purpose trips) K would become 1 thereby making I equal to the total number of inflow workers.

One of the assumptions of this model however is that if people are not shopping from work they are shopping from their place of residence. Subsequently, if less than 100% of the population is engaging in multi-stop, multi-purpose trips ($K < 1$) then those people who are not will be engaging in shopping trips originating from their place of residence (single-stop, single-purpose trips). As a result, it is necessary to re-allocate those people back to their resident census tract and add this to the total demand for that census tract. This group of people is represented in the equation by R. R is determined by first multiplying all of the inflow workers in the matrix by (1-K). This gives the number of people not engaging in multi-stop, multi-purpose trips for each employment census tract j from resident census tract i. Secondly, row totals are obtained for each resident census tract i and these totals will be added to the same corresponding employment census tract. These people who are re-allocated back to their resident census tract are those not engaged in multi-stop, multi-purpose shopping and thus, their trips are residential-based. Those R's however which correspond to census tracts which are not within the study area will not be included. Consequently, it is only those people working outside their resident census tract who will have any effect in altering the spatial distribution of demand as the rest of the population will remain constant.

After knowing how to generate the level of demand for each of the census tract demand nodes or points, it is necessary to determine the combinations of work and residential based trips. The first two obvious combinations are the extremes; all work based (K=1) trips and all residential based trips (K=0). In addition, three combinations within these extremes are selected with 70%, 50% and 30% work based trips equivalent to 30%, 50% and 70% residential based trips respectively. Furthermore, each of those simulations corresponding to the different combinations of shopping trip origins will be referred to as "demand scenarios".

3.4 The Choice of the Study Area

The choice of a particular study area in which to carry out this research is largely determined by a number of factors; the availability of journey-to-work flow data, the ease with which this can be used in the determination of the distribution of demand, its ability to reflect the underlying population base, as well as the availability of retail outlets. Firstly, because this study will be using journey-to-work flows in determining the level of demand under different types of consumer shopping trips and also because this data is only collected for certain Census Metropolitan Areas (CMA's) at infrequent time periods, it is necessary to choose a study area for which this data is available. For instance, this data is available on a census tract scale only for specific CMA's in Canada and is collected every ten years with the most recent collection being 1981 which limits not only the available areas to use in a study but the time at which this data is available.

Another important criterion used in choosing a study area is the availability of various retail chains. More specifically, the particular study area has to be large enough to contain various types of retail chains consisting of numerous outlets. Having a study area with a wide variety of retail chains increases the chance of choosing a chain appropriate for the particular study.

The ease with which the different levels of demand can be generated from the journey to work data is also another consideration when choosing a particular study area. At the moment, the largest scale at which journey-to-work flows are available is at the census tract level. As it was shown in section 3.3, the generation of demand is a time consuming and involved process. For instance, as the number of census tracts in an area increases, the manageability of the data set decreases. Too large of a study area with a large number of census tracts produces increased complexity of consumer travel flows thereby making the model more difficult to calibrate. In addition, it is more difficult to determine the level of demand for each census tract.

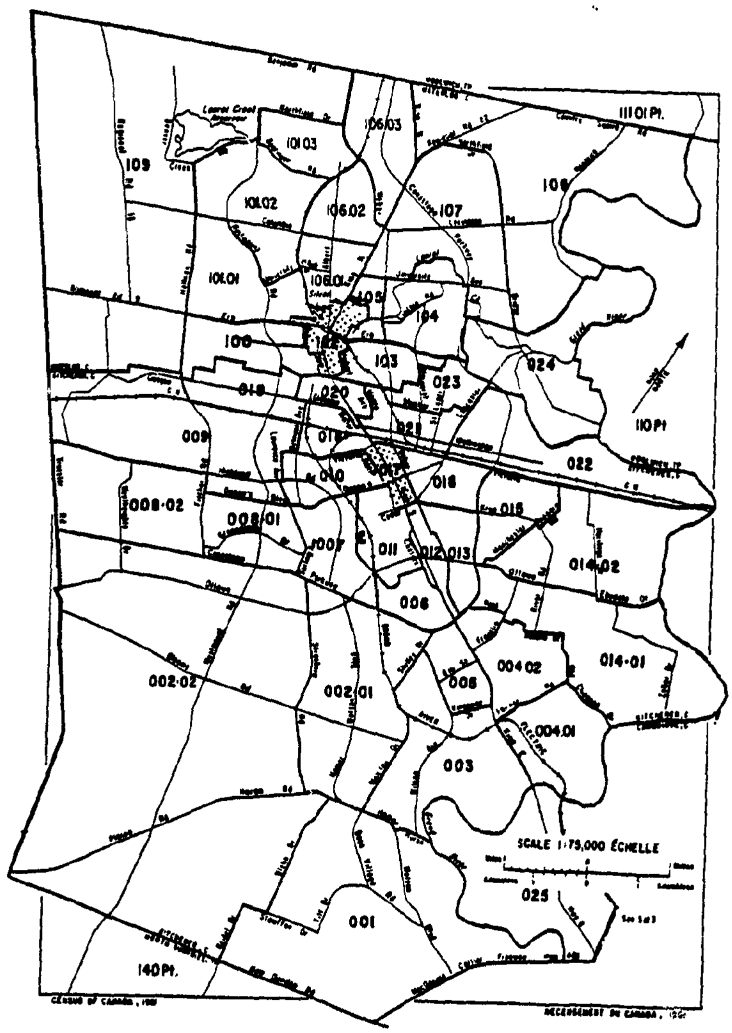
It is evident that the choice of an appropriate study area is dependent not only on the availability of data but also on the ease to which it can be manipulated. As a result, what has become evident is that what is needed is an area which has a sufficient population base consisting of an adequate number of census tracts with corresponding journey-to-work information as well as one containing an adequate variety of retail chains with numerous outlets. Consequently, an area which seems to fit these criteria for this study is Kitchener-Waterloo (Figure 1). For instance, this area represents an almost self-contained market with a sufficient population base of between 200,000 to 300,000 people. It also contains a very manageable but sufficient number of census tracts (43) which reflects the complexities of the population base as a whole. Furthermore, this large population base provides for an area which contains a very diverse retail environment consisting of numerous types of retail chains containing numerous outlets.

3.5 The Choice of a Type of Retail Chain

Another important consideration in a study such as this is the type of retail chain to be used. For instance, the chain which is chosen has to best reflect the types of shopping trips which are to be studied. As it was noted earlier, different types of goods have different types of shopping behaviour associated with them. Stores selling high order goods result in extremely complex shopping behaviour by their consumers while stores selling low order goods are associated with more simplistic shopping behaviour by their consumers. As a result, the chain to be chosen for this study can't sell extremely high order goods as the type of shopping trips in which its consumers engage in are too complex and does not correspond with the simple

Figure 1

Kitchener-Waterloo
1981 Census Tracts



▩ Downtown

Source: Census of Canada 1981
Catalogue 95-915 (Volume 3 - Profile Series A)

concept of multi-stop, multi-purpose trips used in this study. For example, consumers shopping for a high order good will most likely engage in comparison shopping in order to get the best value. Subsequently, their shopping trips will be more sporadic and more complicated than the journey-to-work type trip defined in this study. Also, a suitable chain for this study can't be one which sells extremely low order goods such as convenience stores. These types of stores sell low order goods and are many in number thereby making them easily accessible from almost anywhere in the city. This in turn may make the substitution by a competitor more probable with only slight increases in distance.

It can be seen that the appropriate choice of a chain is largely dependent on the types of products it sells and the types of shopping behaviour most commonly associated with these types of products. Because of this restriction, the type of chain which seems to be best suited to this study is any one of the larger grocery chains. The reason being that the product range associated with these types of stores is not of higher order which alleviates the problem of too complex consumer travel patterns. Also being alleviated is the problem of substitution from convenience stores as the larger grocery stores have a more extensive product range and lower prices thereby obtaining their own niche amongst the various food stores.

3.6 The Components of the Location-Allocation Model

3.6.1 General Overview of the Model

As it was noted earlier, the advantage that the location-allocation model has over the other conventional location methods is its ability to determine the most efficient location configuration of a whole network of stores. In general, its overall concept is that it simultaneously allocates a given spatial distribution of demand to a specified number of outlets by finding a way of locating these facilities according to the objectives of the researcher. In order to apply this model to this particular application its various components must first be defined in a theoretical context and then applied to this particular application.

3.6.2 Demand Points

These points within the location-allocation model are represented by a set of spatial co-ordinates with each point representing a certain level of demand for the goods and services provided. The level of demand associated with each point was described more fully in section 3.3. In this application, like other applications, the demand points are the centroid of the census tracts within the study area. The reason for the choice of census tracts to house these points is that this is one of the smallest levels of data collection in which there are corresponding population figures associated with them. The centroid is used as the point at which the census tract data is allocated largely because of the assumption that demand is evenly distributed within the census tract. This assumption is most accurate when nothing is known about the underlying spatial properties of the data. Subsequently, the demand points for this study are the centroids of the 43 census tracts in Kitchener-Waterloo as defined in section 3.4.

3.6.3 Feasible Sites

The determination of feasible sites for the locations of stores is based on the requirements of the retailer and hence, determine the type of location-allocation model to be used. For instance, in many cases retailers may be concerned about infrastructural restrictions such as the availability of public transit, highways, etc., or planning restrictions such as zoning, land availability etc. As a result, the type of location-allocation model to be used is one in which the set of feasible locations is limited resulting in a location-allocation model in discrete space. In this particular study however it would not be appropriate to choose a discrete model based on these types of infrastructural or planning restrictions. One of the major problems with the inclusion of these factors is that they are prone to change over time as conditions in the economic, political, and demographic environment change. If they were included, this study would only pertain to this specific instance thereby limiting its general applicability. In addition, supermarkets are usually a neighbourhood or community level function and there is generally a wide availability of land zoned for neighbourhood, community level commercial use. The inclusion of zoning changes would probably not decrease the amount of land available for this use. Consequently, including zoning restrictions would probably not significantly affect the locations available to the retailer. As a result, the most appropriate type of location-allocation model would be one in which there were no restrictions on site availability- hence, a continuous space model.

3.6.4 The Number of Outlets to Locate

The number of outlets to locate in the study area is another component of the model and is also determined by the researcher. For instance, as it was noted previously, the location-allocation model can be used in various circumstances. More specifically, it can find the optimal locational configuration of a network of stores in which individual stores are to be added to or deleted from an existing network or the optimal location of an entire network. In the former case, the retailer keeps some locations fixed and adds or deletes outlets based on some set of criteria and then calibrates the model.

This approach would be mainly used by a chain which wants to either increase its market share by the addition of new outlets or deleting outlets in areas of insufficient sales. In the latter case, the retailer decides the most appropriate number of stores to locate which are not fixed and then finds the simultaneous optimal locational configuration. This second option would be used by a retailer wanting to enter a new market by opening multiple outlets all at once in order to maximize market penetration. Because in this particular study we are only concerned with assessing the resultant locational configuration of outlets as a result of varying consumer shopping trips, none of these store locations are added, deleted or fixed. The only variable to be determined is the appropriate number of stores in the network.

In determining the number of stores in the network two options exist. The first option is the selection of a hypothetical number of stores and the second, the total number of stores in the area of an already existing retail chain. The first option was not chosen because of its highly subjective nature which may potentially limit the general applicability of the model. By choosing an existing chain (option 2) and using its existing outlets as the number of outlets to locate in the study area has several advantages. Its main advantage is that using the number of outlets from an existing chain makes the study more realistic and accurate as it is assumed that the retailer must already have an adequate population to support these stores and hence, will have a more accurate measure of the number of stores needed in the area. The importance is that the number of outlets a chain has could be quite different from the number which may be chosen hypothetically.

On the basis of the criteria for the choice of a retail chain described in section 3.5, a chain in Kitchener-Waterloo which fits this criteria is Zehrs. This chain is prominent throughout the region with numerous outlets and has an extensive range of lower order convenience food products. As a result, the number of stores to locate is 15 which is the number of stores in existence at the time in which this study applies, 1981. As a result the only factor that is actually varied is the shopping behaviour of the store's customers.

3.6.5 The Objective Function and Algorithm

One of the most important components of the model is the specification of the objective function and the selection of an algorithm to determine it. The objective function states the conditions to be optimized in selecting store locations and is often some measure of accessibility or economic viability of the outlets. In this particular instance, the objective function is to minimize the overall distance travelled by consumers to shop. Because the number of consumers is represented by a set of demand points, the objective function becomes one which minimizes the overall aggregated weighted distance. The rationale behind having the objective function minimizing the overall aggregated weighted distance is essentially two fold; the first reason being that the products that this chain sells are of lower order and hence, its customers travel to the nearest outlet. Secondly, because this study is concerned with the efficiency of an entire network of stores the best configuration from the consumers' point of view is one in which the overall distance consumers will have to travel will be minimized.

The location-allocation model having an objective function to minimize the overall aggregated weighted distance is extremely common and has become known as the P-median problem. (Ghosh and Rushton 1987)

3.6.6 The P-Median Location-Allocation Model

The general form of this model whose objective is to minimize the overall aggregated weighted distance is shown by the following equation:

$$Z = \sum_{i=1}^{p} \sum_{j=1}^{n} \lambda_{ij} D_j C_{ij}$$

where;

D_j : The demand at location $_j$ (census tract centroid). This demand is the number of people at census tract $_j$ resulting from the demand produced for that census tract under each demand scenario. Each demand scenario consists of the demand created under different combinations of work and residential based trips. (See section 3.3)

C_{ij} : The euclidian distance (straight line distance) between demand point $_j$ and store location $_i$. In this case distance is used as a surrogate for cost because as the distance between the consumer and the store increases so does the cost in terms of travel time, gas etc.

p : The number of stores (15)

n : The number of demand nodes (43)

This equation however is subject to the following constraints;

$$\sum_{i=1}^{p} \lambda_{ij} = 1, \ (j=1,2, \ ...,n)$$

and,

$$\lambda_{ij} = \begin{matrix} 1 & (i=1,2,...,p) \\ 0 & (j=1,2,...,n) \end{matrix}$$

where λ_{ij} is a binary variable. It takes on the value of one if demand point $_j$ is allocated to centre $_i$ and 0 if it is not.

The meaning of the first constraint is that there is no unsatisfied demand. The second constraint is essentially that the demand at $_j$ is not split between stores and hence, each demand point is assigned or allocated to one and only one store. In more general terms, the purpose of the model is to determine the store locations (x_i and y_i) for all stores p and the set of λ_{ij}'s which cause the overall aggregated weighted distance z to be a minimum.

The determination of this objective function requires the identification of a suitable algorithm. One such algorithm which is well suited to continuous space problems and also has the benefit of being relatively simple and quick (Ghosh and Rushton, 1987) and which will be used in the study is the Cooper algorithm. On a more specific note, it first picks the initial starting locations for the stores either randomly or with some prior knowledge of the underlying population. It then divides the demand centres into subsets and for each subset, determines the optimal single store location. It then examines each demand centre to determine if it is possibly closer to one of the other stores than the one to which it was initially allocated. If it is, there becomes the need to change the allocation by locating the stores again and allocate the demand nodes to these new locations. This process is continued alternately re-allocating demand centres and locating stores until the objective function can't go any lower (Cooper, 1964). In this particular study the starting locations chosen were the locations of the centroid of various randomly chosen census tracts. This was done to ensure a better representation throughout the study area as initial runs had indicated sensitivity of the model to different starting solutions.

3.6.7 The Running of the Model

In general terms, this study is using a p-median location-allocation model in continuous space using the Cooper algorithm which was provided by

John Hodgson from the University of Alberta. Five demand scenarios were modelled representing total residential-based trips, 30%, 50%, and 70% work-based trips as well as total work-based trips. One of the weaknesses of the Cooper algorithm is that it produces local optimum solutions. One method which can be used to increase the probability that the local optimum is a global optimum is by doing numerous runs of the model. In this study 500 runs were done for each demand scenario and the solution producing the lowest z function was chosen as the resulting solution for that scenario. In all cases the lowest z function occurred more than once. An example of a typical run can be seen in Appendix 2.

3.7 Analysis

The analysis will look at essentially two problems, the impact varying the spatial distribution of demand will have on the efficiency and success of the network as well as on the spatial location of outlets. Firstly, the efficiency and success of the network will be viewed from two perspectives; the retailers' and the consumers'. From the retailers point of view the most efficient and successful network of stores is one in which the total number of people coming to shop in the study area is maximized and will be referred to as the total market potential. The reason being that since the number of customers is often considered a surrogate for the amount of sales (of which the retailer most often wants to maximize) and hence, the greater the number of customers means a greater the amount of sales.

Another important indicator of efficiency and success for the retailer to consider is the stability of the network. Stability in the sense that the number of customers allocated to each of the stores is fairly equal with little or no variation between stores. For the retailer as well, a stable network is one which produces the least number of stores with allocated customers under the threshold limit which is needed to sustain the outlet. Having a network which has a high degree of variation in the number of customers allocated to each store generally reveals a solution which has outlets with large number of customers and those with very few. This is unstable for the retailer as the store with fewer customers may be subject to closure and the outlets with a large number of customers indicates a potential market for competing stores. In addition, a high variation in the number of customers makes it more difficult for the retailer to standardize operating procedures.

Two techniques will be used to assess the stability of the network in terms of the variation between the number of customers allocated to each store and the number of stores under the threshold limit. In the first case, the coefficient of variation will be computed for the number of customers allocated to each store under each demand scenario. The coefficient of variation is a relative measure of dispersion around the mean and its advantage is that it can give a more accurate view of deviations about the means of two or more distributions (Shaw and Wheeler 1985, p.62). As a result, the scenario with the lowest coefficient of variation is the most stable.

The second method of assessing the stability of the network is the determination of the number of stores under the threshold limit needed to sustain an outlet. The solution which has the smallest number of stores whose customers are under this limit is the most efficient and successful for the retailer. In very general terms it has been found that the total demand needed to sustain a supermarket at the community level with approximately 30,000 square feet is 20,000 people (including children) or 66 people per square foot (Jones and Simmons, 1987, p.68; Jones, 1990; Stason, 1990) The average square footage for Zehrs stores around 1981 was approximately 17,396 square feet (The Directory of Retail Changes in Canada, Vol. 1, 1983). As a result, for a store of 17,396 square feet the minimum demand needed to sustain it is 11,597 persons (17,396 * 0.66). Because however, one of the assumptions of this study is that demand is only represented by the number of adults available to shop, it is necessary to determine the number of adults needed to sustain an outlet.

The first step in determining the number of adults needed to sustain an outlet is to determine the proportion the adults used in this study area to represent demand is of the total population in the study area in 1981. The total number of adults representing consumer demand in this study is 121,700. This is a summation of all adults living in the census tracts in the study area who work outside their resident census tract, who work within their resident census tract, those who work at home as well as those who are not employed. The total population in the study area in 1981 is 183,456 thereby making the proportion of adult customers to the total population 0.66. As a result, the threshold number of customers needed to sustain an outlet becomes approximately 7654 (0.66 * 11597). The demand scenario which produces the least number of stores with allocated customers under this threshold amount will be the most stable solution.

The impact of the efficiency and success of the network from the consumers' perspective is assessed largely on the behaviour of the objective function in the model. The rationale for using the objective function as a measure of efficiency and success from the consumers' perspective is that it is assumed consumers will shop at the nearest outlet and hence, the most efficient network configuration is one which minimizes the overall distance consumers will have to travel. Subsequently, the solution which produces the lowest overall aggregated weighted distance z is the one which may be considered optimal from the consumer's point of view.

By examining success and efficiency from both the retailers' and consumers' perspectives an interesting problem arises. What will be interesting to observe is if the best solution produced in terms of the retailers' perspective is the same for the consumer. This will be illustrated by graphing the z function and the coefficient of variation against the level of multi-stop, multi-purpose trips as well as the total market potential and the z function against the level of multi-stop, multi-purpose trips.

In order to assess the impact on the spatial location of outlets, three techniques are used. The first of these is the creation of individual maps in Terrasoft version 9c of the resulting locations generated under the model for each demand scenario. The rationale behind observing the individual results is that it is possible to see if any specific patterns exist as the level of multi-stop, multi-purpose trips increases or decreases. The second and third of these techniques are used essentially to determine the store locations' sensitivity and insensitivity to changes in the level of multi-stop, multi-purpose trips. More specifically, these techniques are designed to reveal the "hot corners" in the study area in which even under different distributions of demand produced from different types of consumer shopping trips a store location in this area is consistently suggested by the model. In addition, those areas which are highly sensitive to changes in consumer demand are represented by those areas which do not consistently have stores allocated to them under the model.

In order to determine those areas which are sensitive and insensitive to changes in demand two techniques are used to provide an overall summary of the intensity of store locations most frequently and infrequently chosen by the model under all the different demand scenarios. The first technique to be used is a contour map showing two-dimensionally, the intensity of store locations produced simultaneously from all demand scenarios. The second technique will be the creation of a three-dimensional representation of the previously generated contour map. This will reveal those areas which are sensitive and insensitive to changes in consumer demand more easily. For example, areas which are relatively insensitive to changes in demand will be represented by peaks in the demand surface while those areas which are highly sensitive will be relatively flat.

The first step in the generation of this contour map was the determination of the intensity of store locations throughout the area. These intensities were created by first plotting all the resulting locations produced under all of the different demand scenarios and by a method of spatial sampling determining the intensity of stores at each of these locations. More specifically, the centre of a circular area 1/15 the size of the entire study area was superimposed over each point and the number of stores found within it determined the intensity at that point. 1/15 was chosen as the sampling area mainly because this study assumes that the population is evenly distributed throughout the study area, that each store has its own trade and all trade areas are equal and there is no unsatisfied demand in the study.

The second step in the generation of the contour map was the generation of the contours themselves from these densities. The method used for determining the location and pattern of the contours was the triangulation method. In order to observe more easily these results generated from the contour map, a three-dimensional representation was created by digitizing these contours and using the DTM option in Terrasoft version 9c. Census tract boundaries were plotted on top of this 3-dimensional representation to help identify the locations of the areas of high and low store intensity more clearly.

CHAPTER FOUR

RESULTS AND CONCLUSIONS

4.1 Effects on the Efficiency and Success of the Network

4.1.1 Coefficient of Variation

As it was mentioned in Chapter Three, one way success and efficiency of the network from the retailers' perspective is measured by the stability in the system. In this case, stability is indicated by the amount of variation between customers allocated to each store under the different demand scenarios. Firstly, the amount of variation is determined by computing the coefficient of variation for each demand scenario for the number of customers allocated to each store. From examining Table 2 it is evident that the coefficient of variation varies between 36% to 51% with the majority of values in the mid 40% range. The scenario which produces the least amount of variation and hence, is the optimal solution from the retailers' perspective, is the one in which 30% of consumers trips are work-based and 70% residential-based. The next lowest solution produces a coefficient of variation of 42% when 100% of consumer trips are work-based. The next two lowest values are 44%,

Table 2

Number of Customers Allocated to Each Store

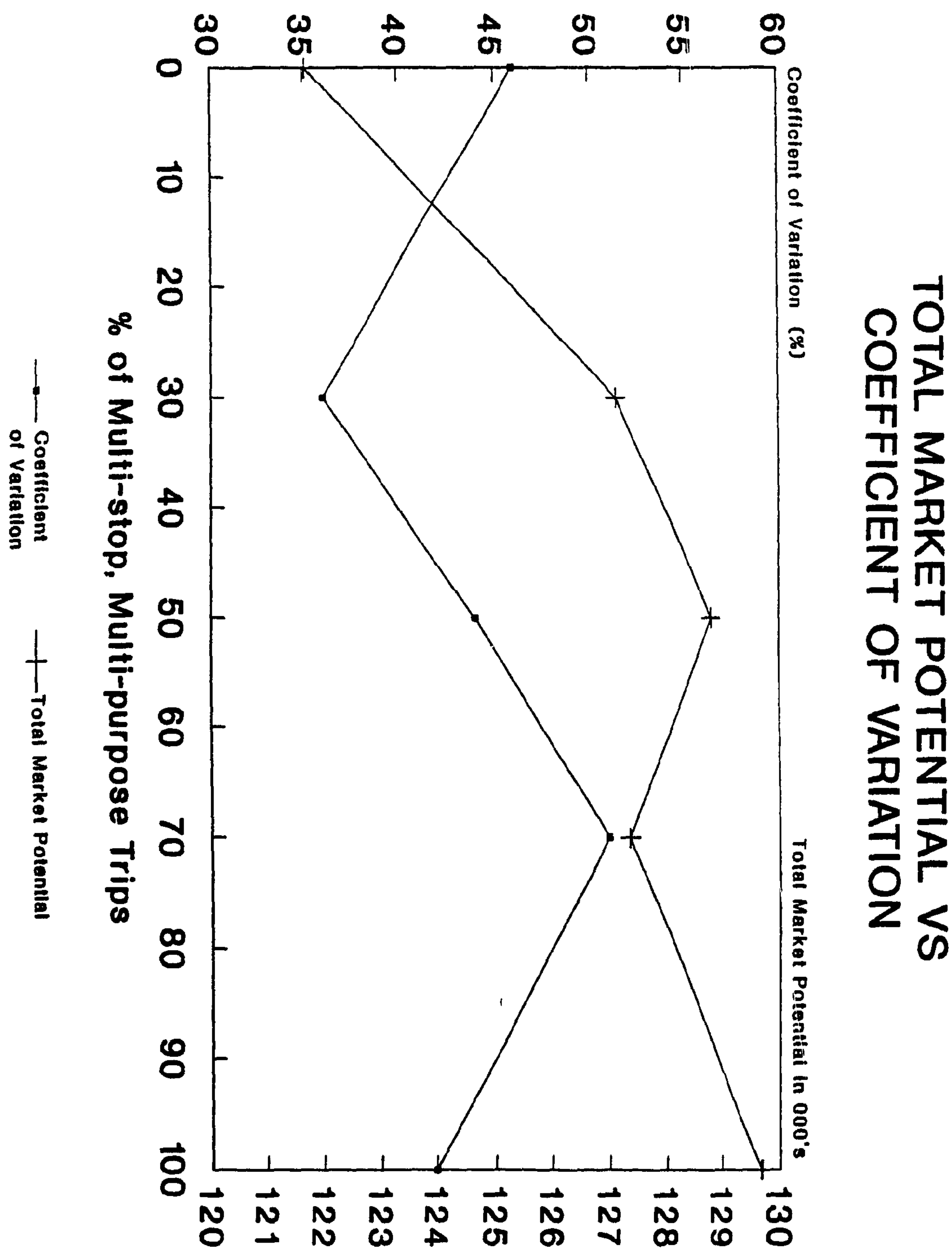
	NUMBER OF CUSTOMERS ALLOCATED TO EACH STORE				
	% of Multi-stop, Multi-purpose Trips				
STORE NUMBER	0%	30%	50%	70%	100%
1	4320	10063	10108	10717	6165
2	6345	3727	6159	6752	8058
3	5755	12911	8056	6216	9035
4	12615	7117	5915	15240	16050
5	3320	9018	9322	14501	9240
6	4750	12104	17129	2102	6925
7	9565	11512	12749	7646	5490
8	16110	8651	9327	7799	15175
9	4940	5619	12451	2926	11495
10	7945	11173	4785	10577	4955
11	6690	4198	7302	2832	9395
12	11495	8061	9403	5555	9495
13	12110	8669	2376	12580	2085
14	11675	2954	11214	6376	11090
15	4065	10467	8541	15560	5050
Total # of Customers	121700	127164	128837	127379	129703
Coefficient of Variation in %	46	36	44	51	42
# of Stores Under Threshold Limit	8	5	5	7	5

46%, for 50% work-based trips and 0% work-based trips (100% residential-based) respectively. The scenario which produces the highest amount of variation and hence, is the worst solution from the retailers' perspective, is the one in which consumer trips are 70% work-based and 30% residential-based. Furthermore, by examining Figure 2 it is evident that there seems to be no relationship between the level of multi-stop, multi-purpose trips and the coefficient of variation. As a result the retailer can't predict what will happen if the percentage of work-based trips changes.

4.1.2 Total Potential Market

One other criterion which is used in this study to assess the success and efficiency of a network of stores is its total market potential. It is essentially the number of customers available in the study area to shop. This market potential is determined by the generation of the total number of customers allocated to all of the stores under each of the different demand scenarios. An examination of Table 2 reveals that overall, under all of the different demand scenarios the total number of potential customers in the system ranges from approximately 121,000 to 130,000. The scenario which produces the largest number of potential customers and hence, is the most optimal for the retailer, is the one in which consumer trips are 100% work-based. The next highest is when trips are 50% work-based. Following these with not much difference

Figure 2



TOTAL MARKET POTENTIAL VS
COEFFICIENT OF VARIATION
Coefficient of Variation (%)
Total Market Potential in 000's
60
55
50
45
40
35
30
130
129
128
127
126
125
124
123
122
121
120
0
10
20
30
40
50
60
70
80
90
100
% of Multi-stop, Multi-purpose Trips
Coefficient of Variation
Total Market Potential

between them, are the scenarios produced from 70% work-based trips and 30%work-based trips. The demand scenario which produces a considerably smaller number of potential customers and is the worst for the retailer, is the one in which all consumer trips are residential-based (0% work-based).

Further examination of Figure 2 reveals that there would seem to be a relationship between the percentage of multi-stop, multi-purpose trips and the total potential market. For instance, with the exception of the demand scenario having 70% work-based trips, as the level of multi-stop, multi-purpose shopping trips increases so does the number of customers available in the area to shop. This does seem logical as most of the population in the surrounding study area most likely commutes to Kitchener-Waterloo for employment.

In order to determine however, the overall solution which is the most successful and efficient from the retailers' perspective in terms of the coefficient of variation and the total market potential, it is necessary to consider the previous results simultaneously. For instance, ideally the best solution for the retailer is the one which maximizes the total number of potential customers and minimizes the variation between the number of customers allocated to each of the stores in the network. By graphing the coefficient of variation and the total number of customers allocated to each store against the level of multi-stop, multi-purpose shopping trips it is easier to determine the demand scenario which produces a solution which fits both criteria.

It is evident when viewing Figure 2 that not one demand scenario produces a solution which has both the maximum number of potential customers and the lowest coefficient of variation. For the retailer this means that the best solution becomes a trade-off between these two criteria. As a result, the optimal demand scenario for the retailer is one which maximizes the distance between the total market potential and the coefficient of variation. For instance, in Figure 2, although the scenario with 100% work-based trips generates the largest amount of potential customers it has the second lowest coefficient of variation. On the other hand, the scenario with 30% work-based trips has the lowest coefficient of variation but has the second lowest total market potential. Similarly, the demand scenario with 70% work-based trips generates the third largest number of potential customers but has the highest amount of variation with the largest coefficient of variation.

It is evident that there is not one scenario which has the lowest coefficient of variation and the highest number of potential customers. As a result, the scenario which maximizes this difference is the most optimal while the one which minimizes this difference is the worst. Subsequently, the optimal solution from the retailers' perspective according to those two criteria is when 100% of shopping trips are work-based. In this case the coefficient of variation is the second lowest and the total market potential is the highest. An explanation for this pattern is that the majority of people in and around this area come to work in Kitchener-Waterloo which increases the overall demand.

The worst scenarios are when shopping trips are 70% and 0% work-based. In the first case, although the total market potential is the second highest, the coefficient of variation is the highest. In the second case, the total market potential is the lowest but the coefficient of variation is the second highest.

4.1.3 The Number of Stores with Customers Under the Threshold Limit

Another criterion which defines the stability in the system is the number of stores which have customers allocated to it under the threshold limit. The threshold limit of customers determined in this study is approximately 7654 (see section 3.7). The optimal solution for the retailer is one which minimizes the number of stores with customers under this limit. From Table 2 it is evident that the best solution for the retailer in terms of the solution having the minimum number of stores whose customers total less than 7654 is when shopping trips are 30%, 50% and 100% work-based. Each of these scenarios have 5 stores under the threshold limit. The worst scenario for the retailer is when shopping trips are 0% and 70% work-based with 8 and 7 stores respectively. Overall however, there seems to be no relationship between the level of multi-stop, multi-purpose trips and the number of stores whose allocated customers are under the threshold limit.

By taking into account all the criteria which determine the best and worst scenarios for the retailer such as; the coefficient of variation, the total market potential and the number of stores whose customers are under the threshold limit per store, some obvious trends emerge. For the retailer the optimal scenario seems to be when shopping trips are 100% work-based. This scenario produces a solution which has the highest potential market, the second lowest coefficient of variation and has the second smallest number of stores with customers under the threshold limit. One of the worst scenarios for the retailer is when shopping trips are all residential-based. This scenario has the second highest coefficient of variation, the lowest market potential and the highest number of stores under the threshold limit. Another scenario which is almost equally suboptimal for the retailer is when 70% of shopping trips are work-based. The solution produced from this simulation generates the highest coefficient of variation, the second largest potential market and has the second highest number of stores (7) whose customers are under the threshold limit.

4.1.4 The Consumers Perspective

From the consumers perspective the most efficient store network is one in which the distance consumers have to travel is minimized. The optimal solution for the consumer is the one which produces the lowest z function (overall aggregated weighted distance). The results from the model are shown in Table 3.

Table 3

Z Function Values for Each Demand Scenario

% Multi-stop, Multi-purpose Trips	Z Function
0	1234299
30	1396013
50	1392422
70	1343800
100	1274604

From the results shown in Table 3, the most efficient locational configuration of stores in terms of the consumers' perspective is the one in which shopping trips originate from the place of residence. The next best solution is the other extreme case in which all consumer trips are work-based. The worst solutions are when shopping trips are 30% and 50% work-based.

One of the implications that arises due to the different criteria that define efficiency and success from both the retailers' and the consumers' perspective is that the solution which is optimal from the consumers' standpoint may not be the same for the retailer. By graphing the coefficient of variation and the z function and the total market potential and the z function, against the level of multi-stop, multi-purpose shopping trips (Figures 3 and 4), it is possible to view both perspectives simultaneously. In the case of Figure 3, if both graphs were to run parallel to each other and the scenario producing the lowest coefficient of variation and the one producing the lowest z function were the same, this would indicate that the results from the retailers' perspective were the same as the consumers. For instance, if both variables were parallel to each other (either increasing or decreasing) this indicates that both perspectives are the same for those demand scenarios as both variables are trying to be minimized.

An examination of Figure 3 reveals that the optimal solution for the retailer is not the same as for the consumer. Firstly, there seems to be

Figure 3

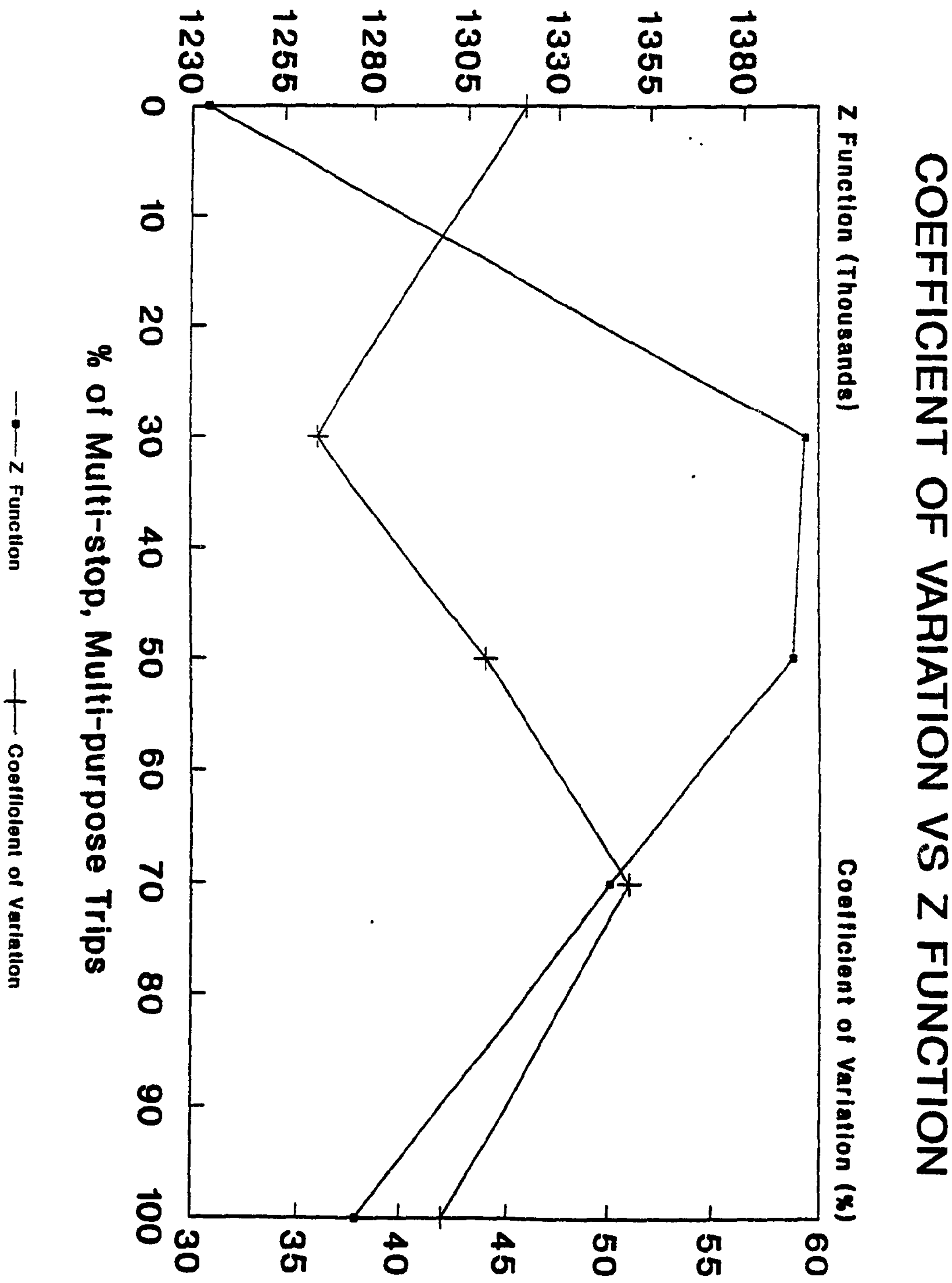
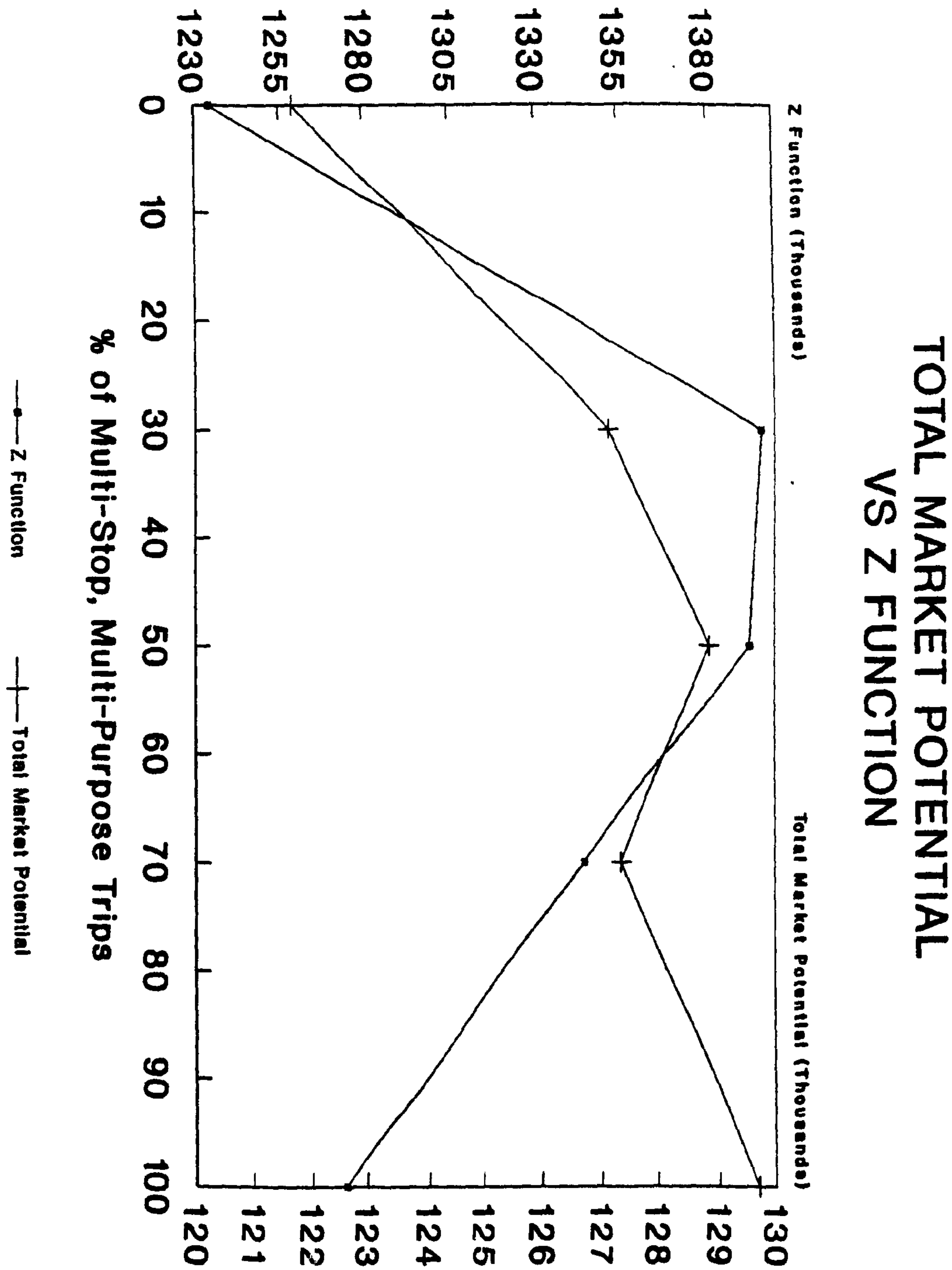

COEFFICIENT OF VARIATION VS Z FUNCTION
Z Function (Thousands)
Coefficient of Variation (%)
1230
1255
1280
1305
1330
1355
1380
30
35
40
45
50
55
60
0
10
20
30
40
50
60
70
80
90
100
% of Multi-stop, Multi-purpose Trips
Z Function
Coefficient of Variation

Figure 4


TOTAL MARKET POTENTIAL
VS Z FUNCTION
Z Function (Thousands)
Total Market Potential (Thousands)
1230
1255
1280
1305
1330
1355
1380
120
121
122
123
124
125
126
127
128
129
130
0
10
20
30
40
50
60
70
80
90
100
% of Multi-Stop, Multi-Purpose Trips
Z Function
Total Market Potential

somewhat of an inverse relationship between the coefficient of variation and the z function. From 0% to 70% multi-stop, multi-purpose trips, as the coefficient of variation increases or decreases the z function is having the opposite response. If perspectives from the retailer and the consumer were the same these two variables would not have an opposite relationship as they are both trying to be minimized. Furthermore, Figure 3 also reveals that the optimal solution for the retailer is when 30% of shopping trips are work-based while the optimal scenario for the consumer is when shopping trips are all residential-based.

These results are also similar in Figure 4 which graphs the total market potential and z function against the level of multi-stop, multi-purpose trips. In this case total market potential and the z function should have an inverse relationship as one is to be maximized while the other minimized. From 0% to 70% work-based trips both of these variables reveal the same pattern. Also, the optimal solution from the retailers standpoint is when trips are all work-based while the best solution for the consumer is when shopping trips are all residential-based. As a result, by comparing all of these results it is evident that the scenario which is optimal for the retailer is not the same as what is optimal for the consumer.

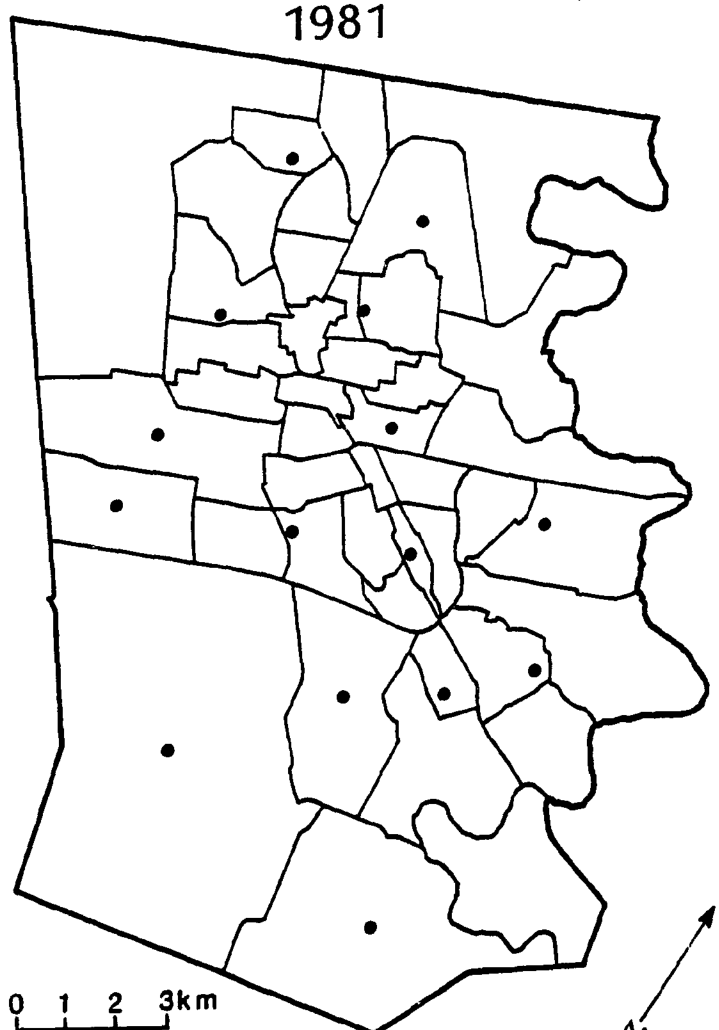
4.2 Effects on the Spatial Location of Outlets

In terms of how the different demand scenarios effect the spatial location of outlets one aspect that can be looked at is the pattern of store locations that results from each individual demand scenario. It is also possible to try and observe if there are any specific patterns that emerge as the level of multi-stop, multi-purpose trips change. In the demand scenario in which trips are all residential-based (Figure 5) there seems to be a fairly even distribution of stores throughout the study area. There are no specific concentrations in the downtown of either Kitchener or Waterloo. Also, there seems to be no pattern in terms of the locations along lineal features such as King St. and the rail lines. A reason for this being that these areas tend to be commercial or industrial areas rather than residential. The areas which are avoided are the census tracts in the north west and north east corners and the census tracts running north and south along the eastern border of the CMA. The obvious reason being that these areas were still under-developed in 1981 and much of the land was comprised of rural farmland. This however may not be the case today as new subdivisions in these areas are continually being developed.

When 30% of consumer trips are work-based (Figure 6) the pattern of store locations is somewhat similar to that found when all trips are residential based. Store locations are still generally evenly distributed and the areas or

Figure 5

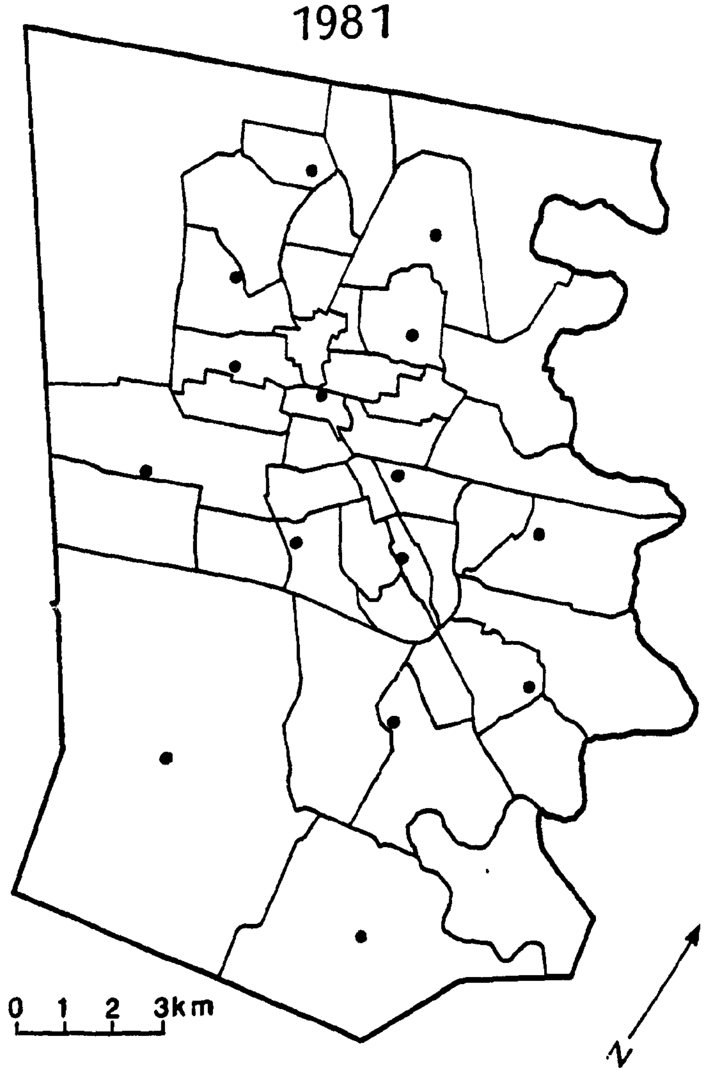
OPTIMAL STORE LOCATIONS
Total Residential-Based Trips
Kitchener-Waterloo
1981



• Store Location

Figure 6

OPTIMAL STORE LOCATIONS
30% Work-Based Trips
Kitchener-Waterloo
1981



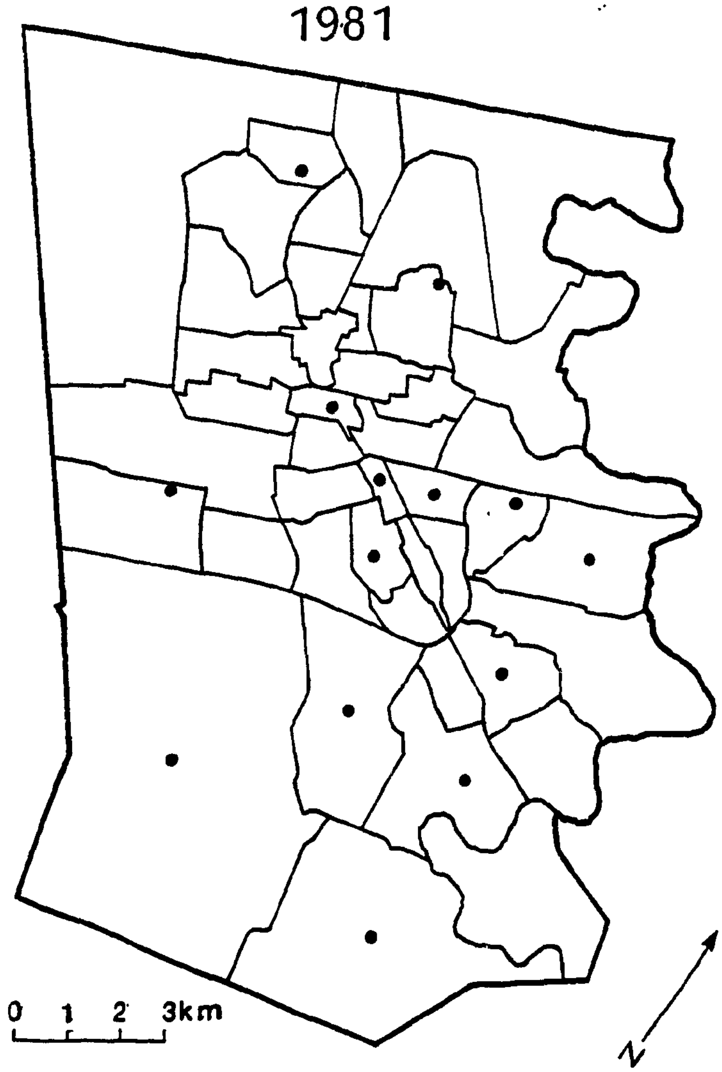
• Store Location

census tracts lacking stores are again in the north east and west corners and along the eastern boundary of the CMA. Overall, store locations have shifted somewhat towards the downtown of both Kitchener and Waterloo. The pattern however revealed when trips are 50% work-based (Figure 7) is quite different. Although there are some census tracts or areas that are consistent in the sense that all of the scenarios so far have located stores in those areas (the south west and one or two in the north central area of Waterloo) there are some variations. There is a greater concentration of stores in and around the downtown and along King St as well as along the rail line which runs east and west through the central part of the study area. A possible reason for this pattern is that as the level of multi-stop, multi-purpose trips increase so does the population coming to work in the area which creates higher demand in those areas. These areas of higher demand in the downtown are centres of commerce while the demand along the rail line exemplifies the higher concentration of industrial employment.

The store location produced under a 70% work-based trips (Figure 8) simulation reveal a less concentrated pattern than the simulation with 50% work-based trips. Although there are two stores located near the Kitchener downtown and one near Waterloo's downtown, the rest of the store locations do not show as concentrated a pattern along King St. and the rail lines. Even under increasing work-based demand, census tracts in the south west are still allocated with outlets. This pattern however is not as dispersed as the solution

Figure 7

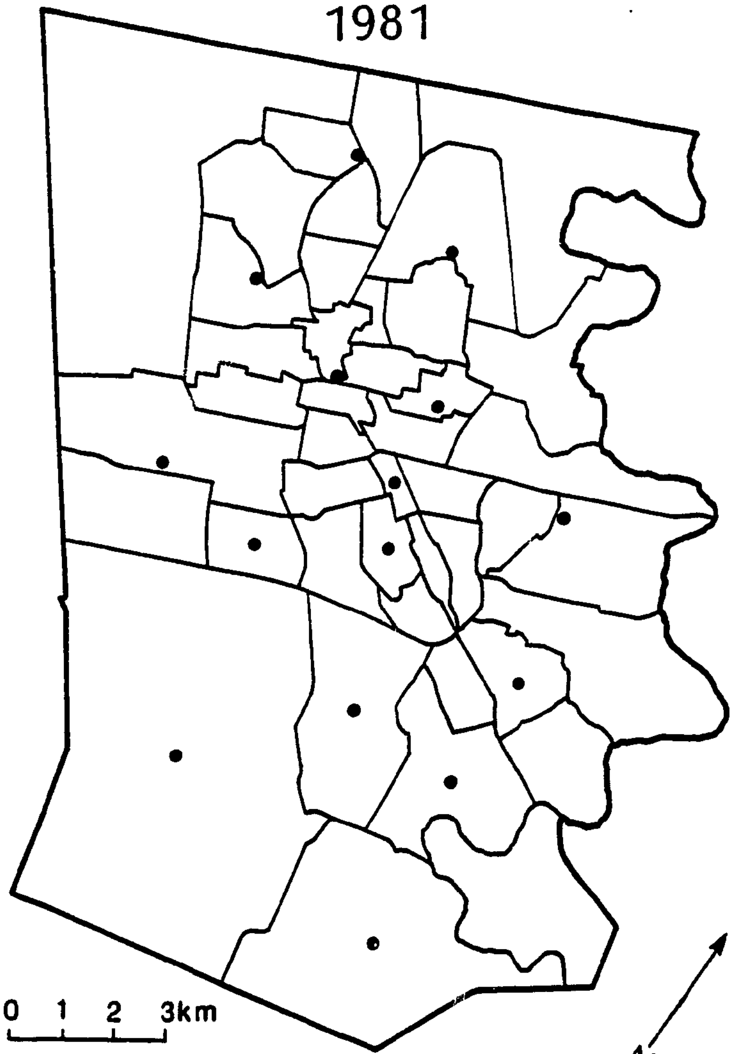
OPTIMAL STORE LOCATIONS
50% Work-Based Trips
Kitchener-Waterloo
1981



• Store Location

Figure 8

OPTIMAL STORE LOCATIONS
70% Work-Based Trips
Kitchener-Waterloo
1981



• Store Location

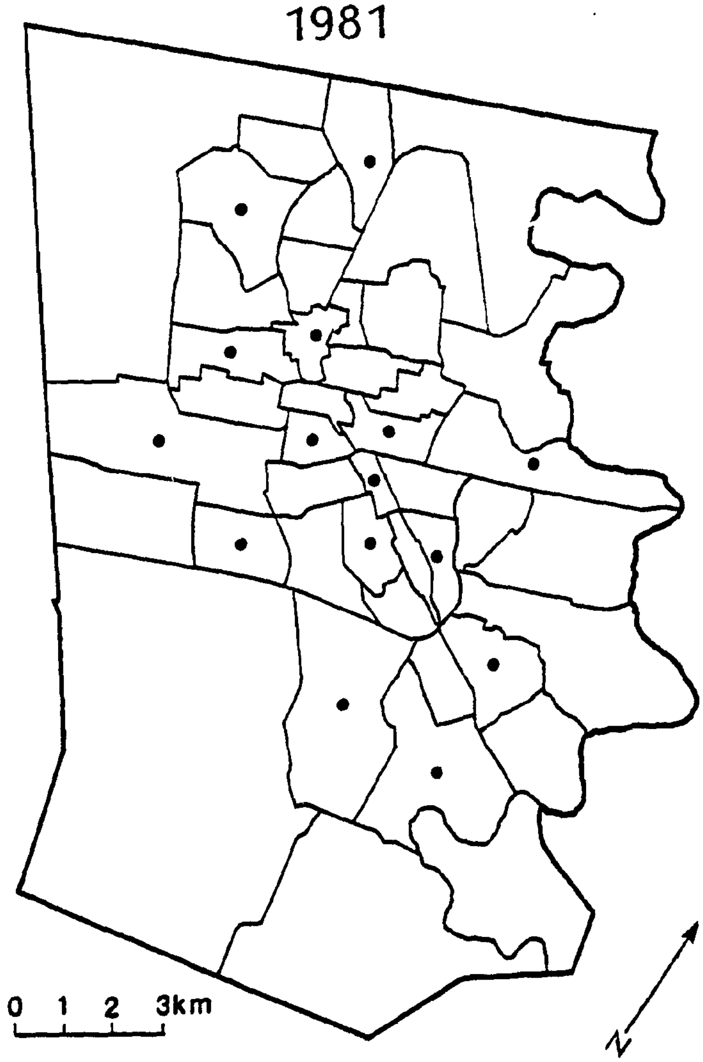
generated from all residential-based trips.

The demand scenario in which consumers trips are all work-based (Figure 9) reveals the most concentrated pattern of all scenarios. Most stores are clustered around Kitchener's downtown with a few in and around Waterloo's downtown as well. The areas which are void of outlets are once again mainly in the north east and north west corners, along the eastern boundary of the CMA and the south west corner. This cluster seems to radiate outwards from the downtown and occupies census tracts which are in close proximity to King St. and the industrial census tracts which are near the downtown are also allocated with outlets.

Overall there seems to be some very general patterns which emerge from the locational configuration generated under the different demand scenarios. Firstly, there seems to be a trend towards a concentration of outlets around the downtown areas as the level of multi-stop, multi-purpose trips increases. Secondly, census tracts in the south west always get allocated a store except when shopping trips are all work-based. The reason for this being that the demand in these areas does not change that much under the different demand scenarios. Other areas which seem relatively unaffected by changes in the spatial distribution of demand are the census tracts in the north west and north east corners and those areas along the eastern border of the CMA. In this case they are largely unaffected as they do not consistently have outlets allocated to them. This is mainly due to low residential and work populations

Figure 9

OPTIMAL STORE LOCATIONS
Total Work-Based Trips
Kitchener-Waterloo
1981



• Store Location

in these areas. Lastly, some of the census tracts in and around the downtown areas consistently have stores allocated to them. An explanation for this may be that there is both a high residential and work population downtown which is most likely a function of the size of the city. Larger cities would most likely have larger commercial areas with proportionately less land available for residential use.

Another aspect to be observed (in terms of the effect varying the spatial distribution of demand has on the spatial location of outlets) is the determination of those areas which are relatively insensitive and sensitive to changes in spatial demand patterns. The importance of this lies in that it will help identify the "hot corners" within Kitchener-Waterloo in which the retailer can locate with success as these locations are relatively unaffected by changes in demand patterns. In addition, it will also help detect those areas which are highly sensitive to changes in the spatial distribution of demand. This would in turn indicate to the retailer areas in which it may not be wise to locate stores. By examining both the contour map (Figure 10) which is generated from determining the intensity of store location produced under all of the scenarios simultaneously, as well as the three dimensional representations (Figures 11,12,13, and 14) , it is possible to identify the "hot corners" as well as those areas which are highly sensitive to changes in demand.

It is evident when observing Figures 10,11,12,13 and 14, that a specific pattern emerges. The highest store intensity lies in the downtown of Kitchener

Figure 10

INTENSITY OF STORE LOCATIONS

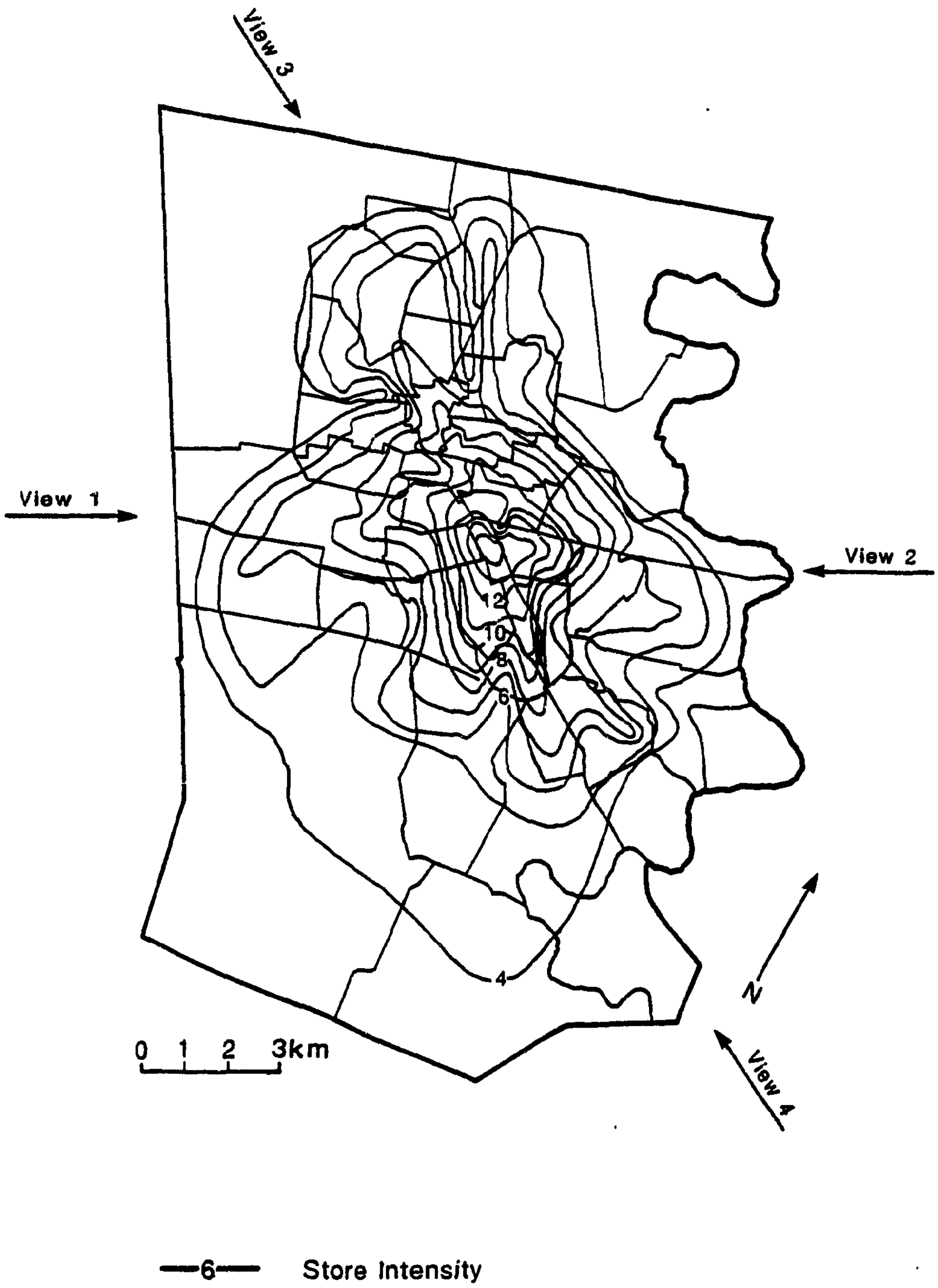
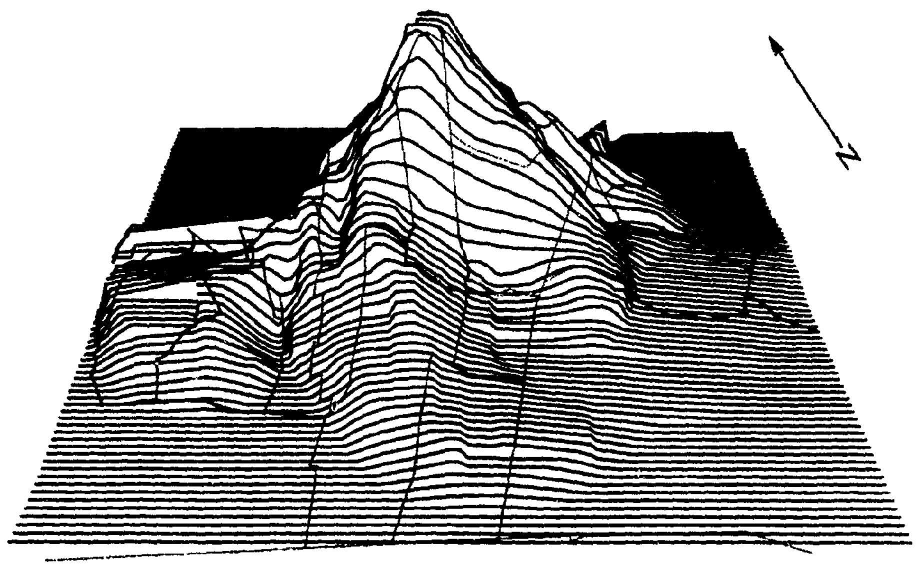


Figure 11

INTENSITY OF STORE LOCATIONS
3-D Representation
View 1



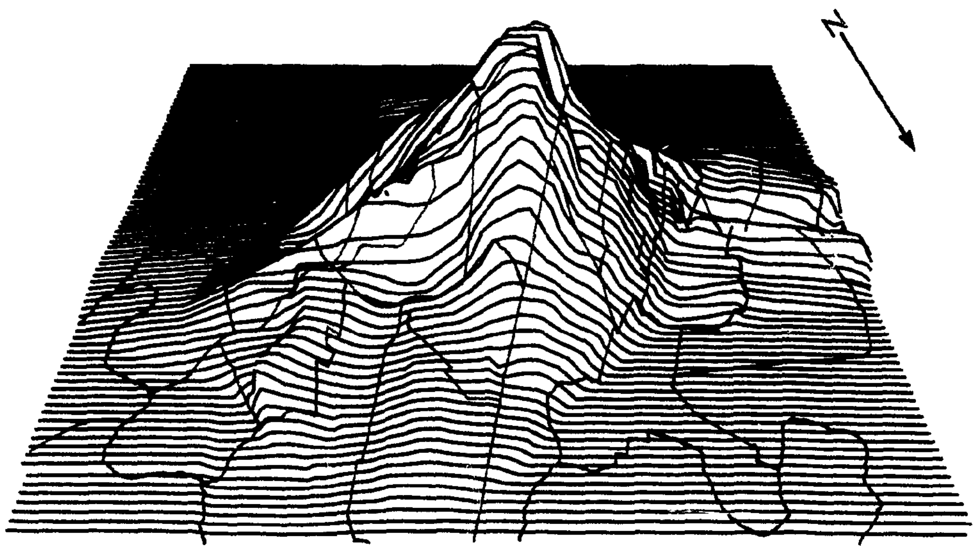
View direction 90°
Angle below horizon -50°
Camera Lens 25mm
X Direction -25m

Y Direction 100m
Height 220m
Elevation scaling .8

—— Census Tract Boundaries

Figure 12

INTENSITY OF STORE LOCATIONS
3-D Representation
View 2



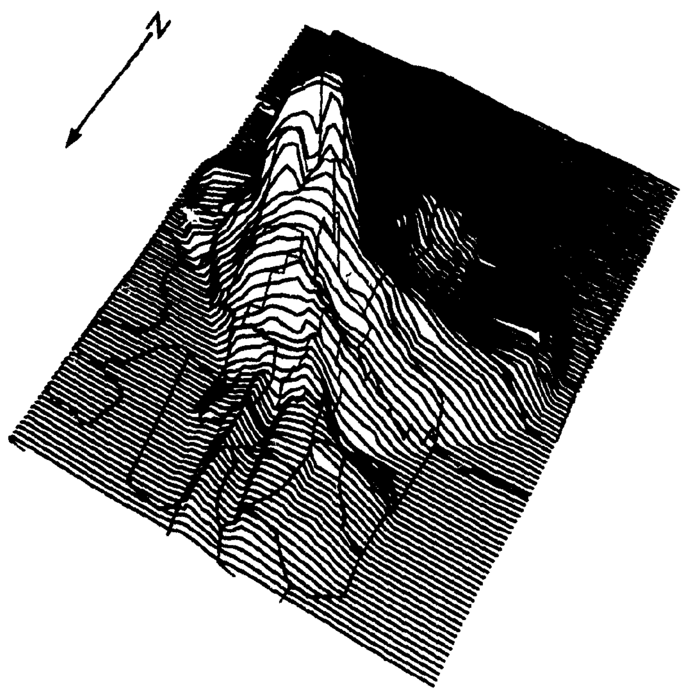
View direction 270°
Angle below horizon -50°
Camera lens 25mm
X Direction 175m

Y Direction 100m
Height 220m
Elevation scaling .8

—— Census Tract Boundaries

Figure 13

INTENSITY OF STORE LOCATIONS
3-D Representation
View 3



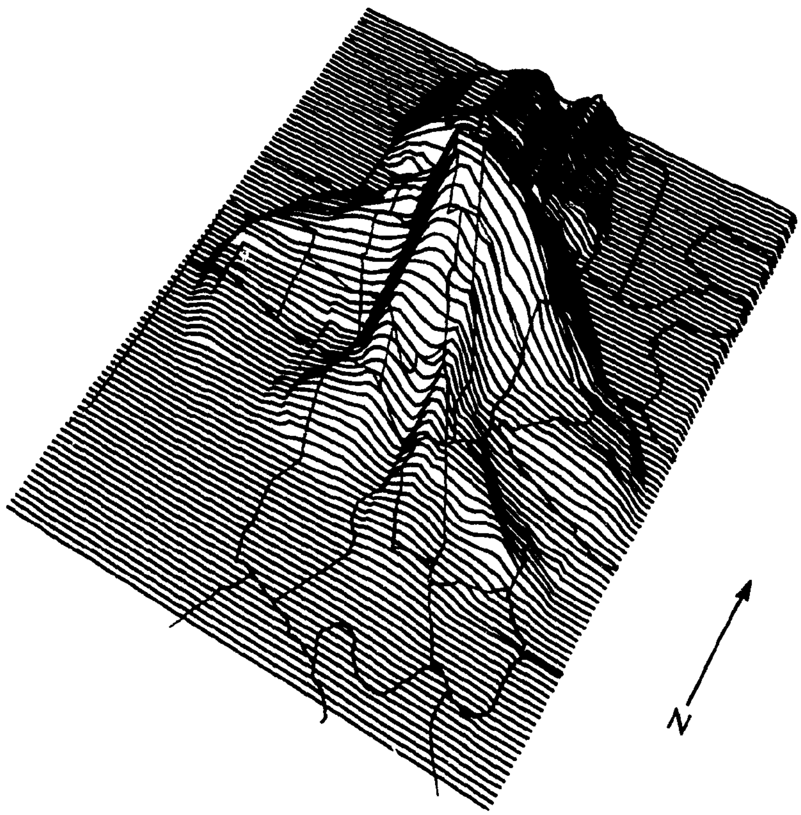
View direction 150°
Angle below horizon -70°
Camera lens 30mm
X Direction 20m

Y Direction 240m
Height 300m
Elevation scaling 1

—— Census Tract Boundaries

Figure 14

INTENSITY OF STORE LOCATIONS
3-D Representation
View 4



View direction 330°
Angle below horizon -70%
Camera lens 35mm
X Direction 150m

Y Direction -5m
Height 320m
Elevation Scaling 1

—— Census Tract Boundaries

and decreases in a concentric pattern from this point outwards. This intensity also seems to follow major roadways such as King St. which runs north to south through the study area and Highway 7 (rail line) which runs east and west through the centre as well. For the retailer this means that the location-allocation model consistently locates stores in and around the downtown regardless of changes in the type of shopping trips consumers engage in. Those areas which are highly sensitive to changes in demand by having low values of store intensity associated with them tend to be in the periphery of the study area. This is especially evident in the north west and south west corners of the study area. For the retailer this means that the level of demand in these areas is not great enough to warrant any outlets.

4.3 Conclusions

The effect of varying the level of multi-stop, multi-purpose trips has produced some interesting effects for both the retailer and the consumer in terms of the efficiency and success of the network. From the retailers' perspective its concerns are to maximize the total number of customers available in the market to shop (total market potential) and minimize variability in the system in terms of the number of customers that get allocated to each store as well as the number of stores which have customers under the threshold limit needed to sustain it. After examining the results from these three criteria the optimal solution for the retailer seems to be when 100% of shopping trips are work-based while the worst is when they are either all-residential-based or 70% work-based. For the consumer however, the optimal solution is when the overall distance travelled to shop is minimized. Subsequently, the optimal solution for the consumer is when shopping trips are all residential-based with the next best being the other extreme, 100% work-based trips.

From the results it is evident that varying the level of multi-stop, multi-purpose trips does effect the efficiency and success of the network from both the consumers' and retailers' perspective. More specifically, the network of store locations which is the most successful and efficient from the consumers' perspective is not the same as the most efficient and successful from the retailers' perspective. Increasing levels of multi-stop, multi-purpose trips produce a more efficient and successful network of stores for the retailer but not for the consumer.

Varying the level of multi-stop, multi-purpose trips not only effects the spatial location of outlets but the results from the different locational configurations of stores indicate the best and worst areas in which to locate an outlet. For example, as the level of multi-stop, multi-purpose trips increased store locations became more concentrated towards the downtown of both Waterloo and Kitchener and along major transportation routes such as King St. and Highway 7 (rail lines). Areas in the north east and north west corners of the study area and along the eastern boundary are constantly void of store locations. In addition Figures 10,11,12,13 and 14, reveal those areas which are highly sensitive to changes in consumer demand by having few stores allocated to these areas. These areas tend to be along all borders of the study area. These figures also reveal those areas which are not sensitive to changes in consumer demand as they are consistently having stores allocated to them under all different demand scenarios which is indicated by the high levels of store intensity. The areas of highest intensity are found in downtown Kitchener and decrease outward.

The importance of revealing areas which are highly sensitive and insensitive to changes in consumer demand is that these areas can provide indications to the retailer as to which areas may be better to locate in. Furthermore, since shopping patterns of consumers' are getting more complex and difficult to model, if a retailer knows which areas are relatively insensitive to changing consumer demand patterns they will be more apt to locate stores in these areas and avoid those areas which are highly sensitive.

CHAPTER 5

SUMMARY AND DISCUSSION

Over the past thirty to forty years geographers have become increasingly concerned about the arrangement of facilities over space. In Canada this has been especially true with respect to the location of retail outlets. The phenomenal growth of the planned shopping centre and the emergence of the retail chain has produced a retail environment which is extremely complex and competitive. In addition, many of Canada's urban centres have grown to such an extent that they have become plagued with some of the same problems such as extremely high land and development costs etc., that were once thought to only be associated with large American cities. At the same time however, changing demographics largely due to the increase in the proportion of women in the work force along with different lifestyle and economic trends etc., has tremendously altered the shopping behaviour of consumers. All of these changes in Canada's retail environment in terms of increases in the complexity of the commercial spatial structure and consumer behaviour, as well as the increased costs in development, have made the opening of a retail outlet a more costly venture.

One of the important consequences that has emerged for the retail firm as a result of these complex changes in the retail environment is the need to more fully understand the shopping behaviour of its consumers, to be able to model this shopping behaviour and to incorporate it into a quantifiable location strategy. The literature which resulted tended to largely model consumers' shopping trips as single-stop, single-purpose trips originating from the consumer's place of residence. Only a few researchers have tried to incorporate more realistic types of shopping trips. In addition, the types of location models which were mainly used were only concerned with the location of one outlet which is inadequate since Canada's retail environment is dominated by retail chains whose marketing strategy often involves the opening of multiple outlets. Even though the location-allocation model was developed in order to deal with a whole network of outlets, when this model was used researchers still modelled shopping trips as single-stop, single-purpose trips. No research has been done explicitly linking more complex consumer shopping behaviour into the location strategy of a whole network of stores. Consequently, it is out of this void in the literature that the basis for this thesis was formed.

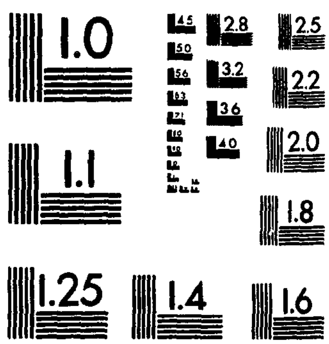
The overall objective of this thesis was to determine the effects variations in consumer shopping trips have on the success and efficiency of a network of stores as well as on the spatial location of outlets. More specific objectives and their methods of implementation were also needed in order to obtain this overall objective. The first of these objectives was to determine a way to define single-stop, single-purpose and multi-stop, multi-purpose shopping trips and incorporate this definition into a workable form. By defining single-stop, single-purpose trips as ones which originate from the home while multi-stop, multi-purpose trips are those which originate from places of employment, it became possible to use the journey-to-work flows from Statistics Canada to determine the resident and work distributions of each census tract. The importance of defining workable definitions of these two types of shopping trips and using the journey-to-work information to determine the flows between resident and employment census tracts is that it provided a means to manipulate different combinations of these types of shopping trips to create different demand scenarios. The journey-to-work flows provided a method to determine the number of people employed in a census tract. Furthermore, by knowing the allocations to these census tracts it was possible to manipulate the number of people coming to work in that census tract from outside to represent the proportion of those engaging in multi-stop, multi-purpose trips.It is also possible to reallocate those not engaging in multi-stop, multi-purpose trips back to their resident census tract to represent the proportion engaged in single-stop, single-purpose trips. By varying these proportions it was possible to determine different combinations of work and residential based shopping trips to create different spatial distributions of demand.

After finding a method to determine different spatial distributions of demand reflecting different combinations of single-stop, single-purpose and multi-stop, multi-purpose shopping trips these different demand scenarios were incorporated into a p-median location-allocation model in continuous space. The results from the location-allocation model provided the means to assess the effects of varying these different spatial distributions of demand in terms of the efficiency and success of the network as well as on the spatial location of outlets. For instance, the model determines the demand nodes which are allocated to each store as well as the total number of people available in the area to shop. By knowing this it was possible to determine indicators of success and efficiency from the retailers' perspective such as the coefficient of variation of the number of customers allocated to each store, the total market potential and the number of stores with customers under the threshold limit needed to sustain an outlet. As a result, the most efficient network configuration was when consumers' trips were all work-based while the worst was when they were all residential-based. In terms of the efficiency and success from the consumers' perspective, with the different demand scenarios the model generated the z function which is the overall distance consumers' have to travel to shop. By assuming consumers want to minimize the distance they have to travel, the demand scenario which produces the lowest z function is the most efficient and successful for the consumer. For example, the optimal solution for the consumer was when all trips were residential-based (unlike that for the retailer).

The resulting spatial locations of outlets produced from each demand scenario also provided a basis to assess the effect of varying the level of multi-stop, multi-purpose trips on the spatial location of outlets. By examining the resultant locational configurations separately, it was possible to see if there were any patterns which emerged. What was evident is that as the level of multi-stop, multi-purpose trips increased, the store locations became more centralized in accordance with the downtown of Kitchener and extended along major transportation routes. In addition, by mapping all of these store locations throughout the study area it was possible to determine those areas which are relatively insensitive to changes in demand ("hot corners") and the areas which are highly sensitive. This was achieved by creating a two-dimensional representation of store intensities in the form of a contour map and using this contour map to create a three dimensional representation in order to give a better visual presentation of these store intensities. What was shown was that areas which had the greatest store intensity and hence, which were insensitive to changes in demand representing the "hot corners" of the study area were found to be highest in the downtown of Kitchener and decreased outward along major transportation routes. Areas which were highly sensitive to changes in demand tended to be along the outside borders of the study area.

Even though the objectives set out in this study were met, there were certain factors which it did not take into account. Firstly, this study did not include competing grocery store chains. Their exclusion was largely because there was no way to determine which store the consumer would choose. Secondly, this study did not take into account the fact that a consumers trip is also modified by where they decide to go after they shop. For instance, this study only considered consumers shopping at the outlet closest to either their place of residence or their place of employment. It did not consider that where they may go after work (eg. recreational centres or service centres) may alter their choice of the place of purchase. The reason this was not considered in this study was mainly because no information exists on where people tend to go after work or what activities the consumer engages in and its location. Also, this type of information is nonexistent and is too complex and variable to be able to be included in a study such as this. Similarly, the two types of shopping trips were defined in their simplest terms for largely the same reasons. For instance, the multi-stop, multi-purpose trip was defined as only having two stops and two purposes with consumers shopping from their place of employment. It did not include stops or purposes other than this such as recreational activity etc., because of the lack of information and the high variability of this information.

In terms of consumer demand, demand in this study did not include the demand created by dependents such as children. The reason for this is that since the location of some of the adults changes from their resident census tract to their employment census tract, there is no way to allocate the corresponding demand associated with each adult to that employment census


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

tract. As a result, it was assumed that demand would be represented by the adults able to shop and that demand was the same for each.

The location-allocation model itself had some weaknesses with it. One of its main weaknesses is that it does not have any upper or lower threshold constraints embedded within it. The importance of this is that a network of stores may result which is not really viable and highly unstable as some outlets do not have enough customers needed to sustain them and some have too many thereby indicating a potential market for expansion-especially for the competition. In addition, one of the constraints in the model is that demand cannot be split between census tracts which assumes that the all of the demand in an area will go to one outlet. It is of course unrealistic to assume that consumers' will behave in this way.

Thirdly, the objective function of the model was to minimize the distance consumers have to travel to shop. Although distance is probably the most important factor determining store choice especially for lower order goods, there are other factors which play a role in store choice which were not included. Some of these include factors such as the availability of other shopping alternatives, services, and parking etc. near the grocery store. Lastly, it did not include other complexities of the spatial environment which would limit possible store locations, the reasons for which were given in section 3.6.3.

It is evident that this thesis has provided some insight into the effects that changes in the spatial demand patterns caused by different types of shopping have on a retail chain in terms of its success and efficiency and on its location strategy. Some of the other factors which were not included as well as some of the limitations provided by the constraints of the model itself provide a good starting point for future research in this area. For instance, future journey-to-work data may include the corresponding demand figures associated with each adult which could then be used to generate the overall demand at places of employment. In addition, more detailed market analyses of the retail chain to be studied should be undertaken to determine a more accurate means to find each outlet's threshold limit. This however is limited by the availability of such data due to the confidentiality which is placed upon this type of information. Furthermore, if this data becomes available an extension of this study could include these values which would then be incorporated into a location-allocation model in order to obtain a more viable solution of store locations. Consequently, the more detailed data on consumer shopping behaviour as well as the financial and marketing information of retail chains in Canada that becomes available, may provide a better basis for future studies.

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Appendix 1

Journey-to-Work Flow Data

Resident Census Tract	Employment Census Tract																					
	1.00	2.01	2.02	3.00	4.01	4.02	5.00	6.00	7.00	8.01	8.02	9.00	10.00	11.00	12.00	13.00	14.01	14.02	15.00	16.00	17.00	18.00
1.00		205	20	420	25	50	5		70		10	10	15	90	40	15	20		20	45	250	50
2.01	30		80	330	85	85	65		95	30	10	25	65	220	70	5	40	30	15	90	350	110
2.02	15	300		100	45	25	35	10	60	20	15	85	55	260	65	5	10	15	15	120	310	100
3.00	20	130			15	60	60		24	5			5	130	55		0	30	5	25	120	96
4.01		135	5	315		80	35		45	15		5	15	55	35	15	5	20	30	65	175	30
4.02	15	215	15	340	110		110	5	15			25	25	195	45	15	10	25	10	30	265	95
5.00	5	340	20	530	40	100		20	75		5	5	20	160	25	5	15	45	5	75	285	105
6.00	10	25	10	80		25	5		25	5		10	15	60	25			5	10	20	45	30
7.00	10	260	15	210	15	45	45	15		20	15	50	65	570	60	10	10	15	25	55	410	140
8.01	35	185	40	205	45	35	30	15	105		35	65	55	165	65	5	10	15	5	30	365	130
8.02	35	180	45	215	80	45	45	10	155	45		80	120	300	65	15		35	15	140	535	180
9.00	5	195	45	280	25	35	30	15	120	5	30		130	265	65	10		5	50	60	400	245
10.00	10	85	20	65	5	15	15	15	105		5	10		120	10	10	5	15	20	50	210	140
11.00	10	90	5	120	5	10	15	10	90	5		15	60		20	10		10		40	315	30
12.00	5	25	15	75	0		15	5	10			25	10	120		5	5	10	15	20	95	15
13.00		65	25	105	30	25	30	10	40	5	5	15	35	100	80		15	20	10	120	225	40
14.01	5	105	20	175	20	70	25	5	30	5	15	20	30	195	55	5		70	25	80	225	75
14.02	10	305	40	300	25	115	85	10	40	5	30	40	20	325	130	20	175		45	160	445	130
15.00	15	115	10	205	40	90	60	15	50	0	15	15	25	365	95	15	10	70		175	400	70
16.00		90	10	130	20	10	10	10	35	15	20	5	40	160	55	10	5	15	35	*	305	60
17.00	5	40	10	15	5	5			10				5	45	10			5	0	40		30

Resident Census Tract	Employment Census Tract																					
	1.00	2.01	2.02	3.00	4.01	4.02	5.00	6.00	7.00	8.01	8.02	9.00	10.00	11.00	12.00	13.00	14.01	14.02	15.00	16.00	17.00	18.00
18.00	5	25		25		0	15		20				20	50	10			5	6	10	125	
19.00	10	65	10	45		15	10		20	5	10	25	15	55	20	6		25	5	65	100	80
20.00	5	20	20	15	5	5	0			10		15	15	105	5			5		15	155	45
21.00		100	5	60	5	20	25		60	0	5	0	55	155	35	10	5	5	20	25	240	175
22.00	5	0	25	25	10				5		15	5		20	5	5				5	45	20
23.00		45	15	120	15	20	10	5	10	5	10	10	5	55	15	5	5	45	15	20	140	45
24.00		60	5	25	5	10			5				15	25	15		10	25		25	75	50
25.00	0	15	5	20	5				5					40				10			20	
100.00	5	50	15	95	10	5	15	5	25	5	20	60	20	80	5	5	10	20	10	60	175	100
101.01	25	60	10	70	20	10	5	5	45	5	10	50	25	50	25	10	5	20	15	55	175	50
101.02																						5
101.03	5	100	10	60	20	10			10	5	10	5	5	105	40	25	0	10	5	60	130	100
102.00	10	5	0	20	5	5		5	10		5			20	5	5		15	0	40	90	25
103.00		40	5	55	25	10	5		10		5	15	20	50	15			5	10			
104.00	5	95	10	115	10	25	10	5	55	5	5	20	45	120	25	5	10	20	15	75	310	115
105.00		20		25		5			10				5	20	15					25	45	25
106.01		25	5	20	5	10	5	5	5	5		5	5	50	15			5		5	115	15
106.02	0	25	10	60	5	5		10	10	5		10	5	25	15			25	10	65	100	60
106.03																						5
107.00	5	80	10	85	5	25	10	5	25		5	25	20	25	20			20	15	70	180	70
108.00		15			5	5						5	5	20				0			15	15
109.00	5	55	5	25			5		10			10	10	25	20			5	5	20	25	15

Resident Census Tract		Employment Census Tract																					
		1.00	2.01	2.02	3.00	4.01	4.02	5.00	6.00	7.00	8.01	8.02	9.00	10.00	11.00	12.00	13.00	14.01	14.02	15.00	16.00	17.00	18.00
110.00			25	15	70		20		10	15		5	5	10	45	5			30	20	30	70	5
111.01			10	10	110	15	5	5		15			10	75	20	15	10	5	10	5	25	75	15
111.02			25	5	30		5	5	5	10	5	5	10	35	35	15			5	5	35	65	65
120.00		20	20	5	50					10			5			5	5		5			5	
121.00		10	65		5	5								5	10	5					10	20	
122.00			45		25	10	5	10		10					5	15		5	5		5	10	5
123.00		15	40		10	5	10	5				5			5	10	5	5	5		10	75	
124.00		5	10		10	5		5						10			5			5		5	
125.00		5	20	5	20	5	5					5				10			10	5		15	
126.01			25	10	10					10					5			5			5	10	
126.02		10	30		65		15	10	15	5		5			15	20			10		5	· 25	
128.00																							5
127.01		5	40	5	45	10	15	15		10				15	10	10		5	5	5	10	20	10
127.02			75		35	15	10	10						5	5	15				10	10	25	20
128.00		5	15	5	30		10								5	15					10	10	
129.00		25	60		80	10	5	10		10			10	10	65	100	15		25		25	70	10
130.00		5	30		10	25		15						5	20	35	10			5	25	25	15
131.00		20	65	10	65	5	5	5	5						10	20	10		15		15	50	5
140.00		10	25		25	5	15	10		5			5		25				5		5	65	10
																					·		
OUTSIDE CMA		100	575	60	480	80	70	80	55	145	25	60	100	65	475	1.4	25	20	130	80	170	615	285

Resident	Employment Census Tracts																					
Census Tract																						
	1.00	2.01	2.02	3.00	4.01	4.02	5.00	6.00	7.00	8.01	8.02	9.00	10.00	11.00	12.00	13.00	14.01	14.02	15.00	16.00	17.00	18.00
WK HOME &	200	620	370	400	160	320	205	40	375	315	290	425	180	540	170	340	205	270	290	430	205	140
WK SAME CT																						
NOT EMPLOYED	895	1105	1290	675	705	1510	1265	280	1790	1600	1290	1705	1205	1100	735	955	1080	2100	1675	1040	445	415

Resident Census Tract	Employment Census Tract																				
	10.00	20.00	21.00	22.00	23.00	24.00	25.00	100.00	101.01	101.02	101.03	102.00	103.00	104.00	105.00	106.01	106.02	106.03	107.00	108.00	109.00
1.00		30	35	80	10			5	20	20	5	55	5	10	15		10	35	35	5	5
2.01	10	85	100	170		15	10	20	50	60		100	45	30	35	20	25	120	35	30	
2.02	10	115	70	120	15	5	15	25	60	55	10	175	35	15	20	20	10	85	65	20	10
3.00		65	65	75		5	10	5	5		40		5	10	30			40	15	5	
4.01	5	70	60	105	10	30	10		10	20	35	100	35	15	15		15	65	20	10	
4.02	5	110	75	115	20	20		15	20	15		75	20	5	25	15	20	95	45	10	5
5.00		80	75	115	10		20	15	30	35	0	85	20	5	35	15	30	65	20	20	
6.00		20	10	35	10	5		5	5	20		35	5		5		15	10	10	5	
7.00		80	115	120	10	10	10	60	30	50		90	50	5	25	20	60	100	30	25	5
8.01		140	85	105	25	5	10	10	45	100	5	145	35	10	30	65	10	140	50	15	
8.02	15	220	30	115	20	30	5	40	45	85	5	220	50	30	5	30	60	75	80	15	5
9.00	15	200	100	170	25	10		55	65	165	10	200	70	35	20	50	45	155	70		5
10.00	25	80	80	80	5	5		35	25	90	5	80	5	30	20	30	25	80	30	15	
11.00		25	70																		
12.00		40	20	40	5			5		20		45		10		10	5	50	25		
13.00		85	5	80	15	10		15		30		55	20	10	10	15	15	60	20		
14.01		65	15	150		10	10		30	20		90	15	5	15	15		80	30	25	
14.02	5	85	105	200	15	25	10	80	45	60	5	175	25	25	25	45	25	125	75	40	
15.00	5	55	95	105	10	5		15	20	60		90	30	10	5	30	15	115	50	30	5
16.00		110	120	100	30	20		15	5	60	30	120	10	10	5	35	20	45	40	10	
17.00		5	15	20						20		35	10			5	10	20	10		

Resident		Employment Census Tract																				
Census Tract																						
		18.00	20.00	21.00	22.00	23.00	24.00	25.00	100.00	101.01	101.02	101.03	102.00	103.00	104.00	105.00	105.01	106.00	106.05	107.00	108.00	109.00
18.00			50	25	65		5		5	10	15	5	50	10		10	10	15	25		10	
19.00			105	30	55	30	10		40	25	85	10	110	30	15	5	15	10	65	25	10	
20.00				55	40			5	30	5	65	5	165	10	15	5	40	5	70	45	20	
21.00		5	110		205	30	15		10	25	30		120	30	5	25	30	30	70	35	10	
22.00				10		65	10		5	0			5	5		5			30	40	5	
23.00			65	100	110		20		10	15	55	10	85	40	25	15	25	10	25	40	20	
24.00			5	20	65	10				15	65	5	60		0	30	25	10	70	35	5	5
25.00											0						5		5			
100.00		15	160	60	70	35	15	5		100	345		310	10	20	95	165	20	70	60	20	25
101.01		5	205	40	50	15	10		25		405	5	375	40	30	40	150	65	165	60	55	20
101.02														5					5			
101.03		5	85	60	125	15	20		35	30	105		255	50	60	60	80	100	405	205	100	20
102.00		5	50	20	25	10			10	30	10	5		20	5	65	35	20	25	20	5	15
103.00																						
104.00			120	95	95	25	5		45	85	105	10	370	65		90	135	80	200	150	80	45
105.00			45	15	20	10			10	20	30		125	10	30		60	5	65	45	0	5
105.01			20	20	50	0		5	30	10	200	5	150	20	20	30		20	80	70	15	10
106.00			65	25	25	5	10		10	10	165	5	115	35	25	35	125		235	75	15	30
106.05												5										
107.00		15	115	60	55	25	40		30	50	135	15	210	35	60	65	105	35	205	.	50	20
108.00			10	5	10		15		5				30	5	10			10	35	10		15
109.00			35	10	25	5	10		15	15	70	30	80	15	10	5	15	15	125	60	25	

Resident Census Tract	Employment Census Tract 10.00	20.00	21.00	22.00	23.00	24.00	25.00	100.00	101.01	101.02	101.03	102.00	103.00	104.00	105.00	106.01	106.02	106.03	107.00	108.00	109.00
110.00	15	15	10	40	10	0	5	5	15	10	5	20	5	10		5	15	25	45	30	5
111.01		20	45	20	10		5	10	10	20		245	5	10	40	25	15	135	30		
111.02	10	20	55	25	10	10		15	20	40	15	65	5	25	20	15	15	106	15	15	0
120.00	5	10		10		20	20		5			10				5	5	5			
121.00	5	25	10										5					5			
122.00		5		15	15		10					20		5				15	10		
123.00	10	15	5	25	5					10	5	5			10			10			
124.00		5		10								5									
125.00	10	5	5	5						5		5			5			10		10	
126.01		5		0		5				5		10			5			5	10		
126.02			15	20			15		0			15	10					5			
126.03			5	5																	
127.01				15			15		5	5						15		15			
127.02	5	5	10	5			5		5			10		0		15	5	15		5	
128.00		5	0	5														5			
129.00		30	10	25			55	20		10		30	5	5				15	10	5	
130.00		10		10		10				5		5					5			15	
131.00	5	15	5	20	10	5	5			5		5		5	5	5		0	10	5	
140.00		20	5	15	5		5	5		5								20	10		
																			.		
OUTSIDE CMA		300	290	310	30	75	5	35	165	300	30	440	60	65	125	180	75	550	175	30	30

Resident	Employment Census Tract																				
Census Tract																					
	10.00	20.00	21.00	22.00	23.00	24.00	25.00	100.00	101.01	101.02	101.03	102.00	103.00	104.00	105.00	106.01	106.02	106.03	107.00	108.00	109.00
WK HOME &	80	240	310	100	60	180	50	430	425	30	305	365	215	340	90	235	225	15	330	95	60
WK SAME CT																					
NOT EMPLOYED	615	915	1375	345	700	525	75	1405	1505	45	1100	700	1115	1515	405	875	745	15	1185	165	240

Appendix 2

Example of Location-Allocation Output

```
15:42 MAY 01 '90 LOW3C.DAWKI093

DRIBBLE ON @ 15:19 05/01/90
!E 6WK3UF1
EDIT DOW HERE
*TYa6c8U-87109
STARTING SOLUTION IS



    115.6146   338.5801   1
     62.5915   310.2362   2
    148.1043   265.5358   3
    127.9620   407.0401   4
     73.4648   329.0160   5
    113.3543   316.7197   6
    115.9318   297.7493   7
     95.5047   389.4616   8
     92.9571   339.4264   9
    161.5051   307.9179  10
    145.7281   382.5847  11
    139.4778   361.2522  12
    187.9659   271.2357  13
    165.5883   211.0609  14
    136.3147   283.8469  15
1SOLUTION
********




0ATTEMPT      1
************


0GROUP       1 SERVES NODES:
qqqqqqqqqq
  22 24 25 34 35
0AT      120.9781      339.6197
0AGGREGATE WEIGHTED DISTANCE =      177688.9140

0GROUP       2 SERVES NODES:
qqqqqqqqqq
   3 11
0AT       67.9752      281.1176
0AGGREGATE WEIGHTED DISTANCE =      249124.2270

0GROUP       3 SERVES NODES:
qqqqqqqqqq
   2  4  6  7
0AT      143.1012      259.3394
0AGGREGATE WEIGHTED DISTANCE =      304009.4530

0GROUP       4 SERVES NODES:
qqqqqqqqqq
  39 40
0AT      120.9440      393.3149
0AGGREGATE WEIGHTED DISTANCE =       36095.1006

0GROUP       5 SERVES NODES:
qqqqqqqqqq
  12
```

```
8c736.00C 0AT      73.4048    329.0160
8c737.00C 0AGGREGATE WEIGHTED DISTANCE =          .C190
8c738.00C
8c739.00C 0GRCUP      6 SERVES NODES:
8c740.00C qqqcqqqqqqqq
8c741.00C   13 21
8c742.00C 0AT     124.4007    317.1799
8c743.00C 0AGGREGATE WEIGHTED DISTANCE =      56404.7280
8c744.00C
8c745.00C 0GRCUP      7 SERVES NODES:
8c746.00C qqqcqqqqqqc
8c747.00C    9 1C 14
8c748.00C 0AT     115.5783    298.5774
8c749.00C 0AGGREGATE WEIGHTED DISTANCE =     145298.7110
8c750.00C
8c751.00C 0GRCUP      8 SERVES NODES:
8c752.00C qqqcqqqqqqc
8c753.00C   31 32 33 38 43
8c754.00C 0AT      98.5129    382.7226
8c755.00C 0AGGREGATE WEIGHTED DISTANCE =     237970.0000
8c756.00C
8c757.00C 0GRCUP      9 SERVES NODES:
8c758.00C qqqcqqqqqqc
8c759.00C   23 3C
8c760.00C 0AT      92.4594    348.6136
8c761.00C 0AGGREGATE WEIGHTED DISTANCE =     206558.9033
8c762.00C
8c763.00C 0GRCUP     1C SERVES NODES:
8c764.00C qqqcqqqqqqqc
8c765.00C   16 18 19 20 26
8c766.00C 0AT     102.0155    307.8472
8c767.00C 0AGGREGATE WEIGHTED DISTANCE =     301142.C470
8c768.00C
8c769.00C 0GROUP     11 SERVES NODES:
8c770.00C qqqcqqqqqqc
8c771.00C   41 42
8c772.00C 0AT     146.6463    383.0094
8c773.00C 0AGGREGATE WEIGHTED DISTANCE =      22604.C150
8c774.00C
8c775.00C 0GRCUP     12 SERVES NODES:
8c776.00C qqqcqqqqqqq
8c777.00C   27 28 36 37
8c778.00C 0AT     14C.7573    356.9997
8c779.00C 0AGGREGATE WEIGHTED DISTANCE =     123145.3520
8c780.00C
8c781.00C 0GROUP     13 SERVES NODES:
8c782.00C qqqcqqqqqqc
8c783.00C    5 17
8c784.000 0AT     182.4350    260.4277
8c785.000 0AGGREGATE WEIGHTED DISTANCE =      67913.6326
8c786.000
8c787.00C 0GRCUP     14 SERVES NODES:
8c788.000 qqqcqqcqqqq
8c789.000    1 29
8c790.000 0AT     126.2135    199.7389
8c791.000 0AGGREGATE WEIGHTED DISTANCE =      13941.2690
8c792.000
8c793.000 0GRCUP     15 SERVES NODES:
8c794.00C qqqcqqqqqc
8c795.00C    8 15
8c796.00C 0AT     14C.?687    294.3634
8c797.00C 0AGGREGATE WEIGHTED DISTANCE =      13893.3036
```

```
8c798.0u0
8c799.0uC
8c800.000
8c801.0uC OVERALL AGGREGATE WEIGHTED DISTANCE =    1773769.3700
8c802.uu0 ************************************
8c803.0u0
8c804.0uC
8c805.0u0 0ATTEMPT     2
8c806.0uC ************
8c807.00C
8c808.0uC
8c809.0u0 0GROUP      1 SERVES NODES:
8c810.0uC qqqcqqcqqqc
8c811.0u0   22 24 25 34 35
8c812.00C 0AT      120.9781     339.6197
8c813.0uC 0AGGREGATE WEIGHTED DISTANCE =     177688.9140
8c814.0uC
8c815.0u0 0GROUP      2 SERVES NODES:
8c816.0uC qqccqqcqqqc
8c817.0uC     3
8c818.0u0 0AT       74.2948     246.9369
8c819.0u0 0AGGREGATE WEIGHTED DISTANCE =            .C071
8c820.0uC
8c821.0uC 0GROUP      3 SERVES NODES:
8c822.0uC qqccqqcqqqc
8c823.CuC    2  4  7
8c824.0uC 0AT      135.3966     255.9613
8c825.0u0 0AGGREGATE WEIGHTED DISTANCE =     206786.5700
8c826.0uC
8c827.000 0GROUP      4 SERVES NODES:
8c828.CuC qqqqqqqqq.q
8c829.0u0   33 39 40
8c830.000 0AT      113.8156     400.4485
8c831.0uC 0AGGREGATE WEIGHTED DISTANCE =      77182.8125
8c832.0u0
8c833.0u0 0GROUP      5 SERVES NODES:
8c834.000 qqccnqcqnqq
8c835.0u0   11 12
8c836.000 0AT       69.1517     321.5666
8c837.0u0 0AGGREGATE WEIGHTED DISTANCE =      95735.C391
8c838.0u0
8c839.0uC 0GROUP      6 SERVES NODES:
8c840.000 qqqcqqcqqqc
8c841.0u0   13 20 21
8c842.00C 0AT      130.9907     317.3058
8c843.0CC 0AGGREGATE WEIGHTED DISTANCE =     110788.1170
8c844.000
8c845.0u0 0GROUP      7 SERVES NODES:
8c846.CuC qqqcqqcqqqc
8c847.CUC    9 10
8c848.00C 0AT      107.4236     299.2651
8c849.000 0AGGREGATE WEIGHTED DISTANCE =      92332.8750
8c850.000
8c851.0UC 0GROUP      8 SERVES NODES:
8c852.0u0 qqqqqqqqqqq
8c853.000   31 32 38 43
8c854.0u0 0AT       94.0036     372.3982
8c855.00C 0AGGREGATE WEIGHTED DISTANCE =     125650.9440
8c856.000
```

```
86857.000 0GROUP     9 SERVES NODES:
86858.000 qqqcqqcqqqc
86859.000   23 30



86860.000 0AT       92.4594     348.6136
86861.000 0AGGREGATE WEIGHTED DISTANCE =       20538.9035
86862.000
86863.000 0GROUP    10 SERVES NODES:
86864.000 qqqcqqcqqqc
86865.000   18 19 26
86866.000 0AT      175.3672     305.1919
86867.000 0AGGREGATE WEIGHTED DISTANCE =      148650.4640
86868.000
86869.000 0GROUP    11 SERVES NODES:
86870.000 qqqcqqcqqqc
86871.000   41 42
86872.000 0AT      146.6463  .  363.0094
86873.000 0AGGREGATE WEIGHTED DISTANCE =       22604.0156
86874.000
86875.000 0GROUP    12 SERVES NODES:
86876.000 qqqcqqcqqqc
86877.000   27 28 36 37
86878.000 0AT      140.7575     356.9997
86879.000 0AGGREGATE WEIGHTED DISTANCE =      120145.3520
86880.000
86881.000 0GROUP    13 SERVES NODES:
86882.000 qqqcqqcqqqc
86883.000    5  6 17
86884.000 0AT      171.9597     264.6252
86885.000 0AGGREGATE WEIGHTED DISTANCE =      126821.8120
86886.000
86887.000 0GROUP    14 SERVES NODES:
86888.000 qqqcqqcqqqc
86889.000    1 29
86890.000 0AT      126.2135     199.7389
86891.000 0AGGREGATE WEIGHTED DISTANCE =       15941.2896
86892.000
86893.000 0GROUP    15 SERVES NODES:
86894.000 qqqcqqcqqqc
86895.000    8 14 15 16
86896.000 0AT      137.0615     297.7984
86897.000 0AGGREGATE WEIGHTED DISTANCE =       81012.8359
86898.000
86899.000
86900.000
86901.000 OVERALL AGGREGATE WEIGHTED DISTANCE =    1430679.5000
86902.000 -----------------------------------
86903.000
86904.000
86905.000 0ATTEMPT    3
86906.000 ************
86907.000
86908.000
86909.000 0GROUP     1 SERVES NODES:
86910.000 qqqcqqcqqqc
86911.000   22 24 34 35
86912.000 0AT      116.8685     342.1545
86913.000 0AGGREGATE WEIGHTED DISTANCE =      105063.5030
86914.000
```

```
8c915.000 0GROUP     2 SERVES NODES:
8c916.000 qqqcqqcqqqq
8c917.000     3
8c918.000 0AT      74.2948    246.9569
8c919.000 0AGGREGATE WEIGHTED DISTANCE =          .0071
8c920.000
8c921.000 0GROUP     3 SERVES NODES:



8c922.000 qqqcqqcqqqc
8c923.000    2  4  7
8c924.000 0AT     135.3960    255.9613
8c925.000 0AGGREGATE WEIGHTED DISTANCE =    208786.5700
8c926.000
8c927.000 0GROUP     4 SERVES NODES:
8c928.000 qqqcqqcqqqc
8c929.000   33 39 40
8c930.000 0AT     113.8153    400.4483
8c931.000 0AGGREGATE WEIGHTED DISTANCE =     77182.8125
8c932.000
8c933.000 0GROUP     5 SERVES NODES:
8c934.000 qqqcqqcqqqq
8c935.000   11 12
8c936.000 0AT      69.1517    321.5660
8c937.000 0AGGREGATE WEIGHTED DISTANCE =     95735.0391
8c938.000
8c939.000 0GROUP     6 SERVES NODES:
8c940.000 qqqcqqcqqqc
8c941.000   13 20 21 25
8c942.000 0AT     132.3880    319.2840
8c943.000 0AGGREGATE WEIGHTED DISTANCE =    161531.6090
8c944.000
8c945.000 0GROUP     7 SERVES NODES:
8c946.000 qqqcqqqqqqc
8c947.000    9 10
8c948.000 0AT     107.4230    299.2651
8c949.000 0AGGREGATE WEIGHTED DISTANCE =     92332.8750
8c950.000
8c951.000 0GROUP     8 SERVES NODES:
8c952.000 qqqcqqcqqqq
8c953.000   31 32 36 43
8c954.000 0AT      94.0036    372.3982
8c955.000 0AGGREGATE WEIGHTED DISTANCE =    125650.8440
8c956.000
8c957.000 0GROUP     9 SERVES NODES:
8c958.000 qqqcqqcqqqc
8c959.000   23 30
8c960.000 0AT      92.4594    348.6136
8c961.000 0AGGREGATE WEIGHTED DISTANCE =     26538.9035
8c962.000
8c963.000 0GROUP    10 SERVES NODES:
8c964.000 qqqcqqcqqqq
8c965.000   18 19 26
8c966.000 0AT     175.3672    305.1919
8c967.000 0AGGREGATE WEIGHTED DISTANCE =    148650.4840
8c968.000
8c969.000 0GROUP    11 SERVES NODES:
8c970.000 qqqcqqqqqqc
8c971.000   41 42
8c972.000 0AT     146.6465    363.0094
8c973.000 0AGGREGATE WEIGHTED DISTANCE =     22604.0156
8c974.000
```

```
8c975.0uC 0GROUP    12 SERVES NODES:
8c976.0uC qqqcqqqqqqq
8c977.0uC   27 28 36 37
8c978.0GC 0AT      14C.7573     356.9997
8c979.0uC 0AGGREGATE WEIGHTED DISTANCE =     123145.352u
8c98C.0uC
8c981.0uC 0GROUP    13 SERVES NODES:
8c982.CuC qqqcqqqqqqq
8c983.0u0    5  6 17


8c984.0u0 0AT      171.7597     264.6252
8c985.0u0 0AGGREGATE WEIGHTED DISTANCE =     126821.812u
8c986.0uC
8c987.0uC 0GROUP    14 SERVES NODES:
8c988.0u0 qqqcqqcqqqc
8c989.0uC    1 29
8c990.0u0 0AT      126.2135     199.7389
8c991.0u0 0AGGREGATE WEIGHTED DISTANCE =      15941.2896
8c992.0uC
8c993.0uC 0GROUP    15 SERVES NODES:
8c994.0uC qqqcqqqqqqc
8c995.CuC    3 14 15 16
8c996.CuC 0AT      137.0615     297.7984
8c997.0uC 0AGGREGATE WEIGHTED DISTANCE =      81012.8359
8c998.0uC
8c999.0uC
87C0C.0uC
87001.0u0 OVERALL AGGREGATE WEIGHTED DISTANCE =    1408997.62Cu
87002.0u0 ----------------------------------
87003.0uC
87004.0uC
87005.0CC 0ATTEMPT    4
87006.Cu0 ************
87007.0uC
87008.0uC
87009.0uC 0GROUP     1 SERVES NODES:
8701C.0uC qqqcqqcqqqc
87011.0uC   22 24 34 35
87012.CuC 0AT      116.3685     342.1545
87013.0uC 0AGGREGATE WEIGHTED DISTANCE =     105063.5uuu
87014.0uC
87015.0u0 0GROUP     2 SERVES NODES:
87016.CuC qqqcqqcqqqq
87017.0uC    3
87018.0uC 0AT       74.2948     246.9369
87019.0uC 0AGGREGATE WEIGHTED DISTANCE =           .Cu71
8702C.0uC
87021.0uC 0GROUP     3 SERVES NODES:
87022.0u0 qqqcqqqqqqq
87023.0uC    2  4  7
87024.0uC 0AT      135.3966     255.9613
87025.CuC 0AGGREGATE WEIGHTED DISTANCE =     208786.57Cu
87026.0u0
87027.0uC 0GROUP     4 SERVES NODES:
87028.0uC qqqcqqqqqqq
87029.LLC   33 39 4u
8703C.0CC 0AT      113.8156     400.4483
87031.0u0 0AGGREGATE WEIGHTED DISTANCE =      77182.8125
87032.0u0
```

```
87033.000 0GROUP     5 SERVES NODES:
87034.000 qqqcqqqqqqc
87035.000    11 12
87036.000 0AT       69.1517      321.5666
87037.000 0AGGREGATE WEIGHTED DISTANCE =        95735.0591
87038.000
87039.000 0GROUP     6 SERVES NODES:
87040.000 qqccqqcqqqc
87041.000    20 21 25
87042.000 0AT       136.6044     320.3492
87043.000 0AGGREGATE WEIGHTED DISTANCE =       100890.3520
87044.000
87045.000 0GROUP     7 SERVES NODES:


87046.000 qqccqqcqqqc
87047.000     9 10 13
87048.000 0AT       109.2080     302.9917
87049.000 0AGGREGATE WEIGHTED DISTANCE =       139990.0030
87050.000
87051.000 0GROUP     8 SERVES NODES:
87052.000 qqqcqqcqqqc
87053.000    31 32 33 43
87054.000 0AT        94.0036     372.3982
87055.000 0AGGREGATE WEIGHTED DISTANCE =       125650.8440
87056.000
87057.000 0GROUP     9 SERVES NODES:
87058.000 qqqcqqcqqqc
87059.000    23 30
87060.000 0AT        92.4594     348.6136
87061.000 0AGGREGATE WEIGHTED DISTANCE =        26538.9035
87062.000
87063.000 0GROUP    10 SERVES NODES:
87064.000 qqqcqqqqqqc
87065.000    18 19 26
87066.000 0AT       175.3672     305.1919
87067.000 0AGGREGATE WEIGHTED DISTANCE =       148650.4840
87068.000
87069.000 0GROUP    11 SERVES NODES:
87070.000 qqccqqcqqqq
87071.000    41 42
87072.000 0AT       146.5463     383.0094
87073.000 0AGGREGATE WEIGHTED DISTANCE =        22604.0156
87074.000
87075.000 0GROUP    12 SERVES NODES:
87076.000 qqccqqcqqqc
87077.000    27 23 36 37
87078.000 0AT       140.7573     356.9997
87079.000 0AGGREGATE WEIGHTED DISTANCE =       173145.3520
87080.000
87081.000 0GROUP    13 SERVES NODES:
87082.000 qqqcqqcqqqc
87083.000     5  6 17
87084.000 0AT       171.9397     264.6252
87085.000 0AGGREGATE WEIGHTED DISTANCE =       126821.8120
87086.000
87087.000 0GROUP    14 SERVES NODES:
87088.000 qqqcqqqqqqq
87089.000     1 29
```

```
87090.000 0AT      126.2135     199.7389
87091.000 0AGGREGATE WEIGHTED DISTANCE =      13941.2896
87092.000
87093.000 0GROUP    15 SERVES NODES:
87094.000 qqqqqqqqqqq
87095.000    8 14 15 16
87096.000 0AT      137.0815     297.7984
87097.000 0AGGREGATE WEIGHTED DISTANCE =      81012.3359
87098.000
87099.000
87100.000
87101.000 OVERALL AGGREGATE WEIGHTED DISTANCE =     1396013.5000
87102.000 ------------------------------------
87103.000
87104.000
87105.000 0ATTEMPT    5
87106.000 ************
87107.000



87108.000
87109.000 0NO CHANGE IN GROUP   1396013.5000
*
*E
!DONT DRIBBLE
DRIBBLE OFF : 15:21 05/01/90
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