A Systematic Approach to Location Selection For Shopping Mall Projects

By

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

China is a country which has been developed very quickly since beginning of 90s. Especially, it has got a remarkable increasing investment in real estate industry because of the rapid growth of economy and the demand of higher living standard from the growing population.

Shopping mall development has become one of hottest point in real estate investment project. Location selection is the first stage of decision making in any investment projects. This particularly true to a shopping mall development project. How to choose a right place to develop a right project is the key decision for shopping mall project investments. However, it is still a difficult problem to scientifically select a suitable location.

The thesis starts by providing an overview of location selection methods, methods for shopping mall location selection, the analytical network processing method (ANP), and the Geographical Information System (GIS) were also reviewed. Based on the review of current methods for location selection, this study selected and integrated the DEA (Data Envelopment Analysis) and the ANP (Analytic Network Process) to develop a method for solving location selection problems. A GIS (Geographic Information System) based location selection system was implemented

to test the location selection method. A shopping mall selection problem was chosen to illustrate the usefulness of the location selection system developed in this study.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BIOPM	Binary Integer Liner Program Model
CA	Competitive Advantage
CR	Consistency Ratio
CVS	Convenience Store
DBMS	Database management system
DEA	Data Envelopment Analysis Model
DMU	Decision Making Units
EBP	Error Back- propagation
ESRI	Environmental Systems Research Institute
GDP	Gross Domestic Product
GIS	Geographic Information Systems
MCDM	Multi-Criteria Decision-Making
OS	Operating System
QFD	Quality Function Deployment
ROI	Return on Investment

CHAPTER 1 INTRODUCTION

This thesis presents shopping mall location selection methods and the application of GIS to location selection problems. The research is pursued alone two equally important parts: Exploring location selection methods and the application of GIS system. Location selection methods mathematically integrate location factors. A GIS system provides a platform to vividly display factors related to a location selection problem in a map. Combining location selection methods with a GIS system enables decision makers to have a clear understanding of the location selection problem so that better decisions may arrive. In this chapter, the research scope, objective, research methodology and the organization of the thesis are presented.

1.1 Research Focus

In this research, location selection refers to problems related to selecting locations for real estate development investment projects. At the beginning of any investment project, normally, decision makers need to analyze its economical, technical and environmental feasibility (Xu and Chao 2002). Location selection forms an important part of the feasibility study. The current practice of location selection, however, does not involve a rigorous and scientific procedure, as in most cases, location is selected based on some experiential process that is largely implicit and unstructured (Owen and.Daskin 1998).

This study aims to adapt location selection methods, which have been developed in other domains, such as the retailing industries and manufacturing industries, into the real estate and construction industry. Based on the existing methods, this study identifies and develops location methods for real estate development projects. In addition, this study integrates location selection methods with the GIS system so that decision makers can have a clear understanding and better decision of the location selection problem.

1.2 Research Objective

Although selecting a proper location for real estate development is crucially important, location selection decision appears to be rudimentary and experiential. The primary objective of this research is to explore a systematic and quantitative method to support the location selection making decision process in real estate investment projects.

1.3 Research Methodology

The research methodology comprises the following steps:

- A thorough literature review results in a summary of location selection methodologies and theories which provide a basis for this study to develop its own location selection methods suitable for real estate investment projects.

- Based on the literature review and consequent analyses on the strengths and weaknesses of existing location selection methods, the DEA (Data Envelopment Analysis), AHP (Analytical Hierarchical Processing), and ANP (Analytical Network Processing) methods are chosen to apply in this research.

- Based on the DEA, AHP and ANP, a location selection system has been developed and implemented in the GIS (Geographical Information System) environment. The location selection for a shopping mall was selected as a case study to evaluate the GIS based location selection system developed in this study.

1.4 Organization of the Dissertation

There are seven chapters in this dissertation. These chapters are organized according to their relationships with the objective of the research. Chapter 2 presents a literature review of location selection methods developed in various domains including retailing, manufacturing and logistics. Other useful tools including the AHP and ANP methods, as well as the GIS systems and their applications in location selection are also reviewed.

Chapter 3 explores the location selection methods that are appropriate for fixed investment in the construction field. One of the major considerations of whether to undertake a construction project is to determine if the location is valuable for investment. The Chapter presents the DEA and Binary Integer Linear Program models for location selection problems of fixed investment in the construction field.

Chapter 4 presents the employment of the ANP to select the best site for a shopping mall. It is suggested that ANP is appropriate for shopping mall location selection. In order to explicate the difference between ANP and AHP, the findings obtained from the two methods are compared. Results of the comparison indicate that ANP is powerful tool to solve the decision problem if interdependent relationships have substantial impacts in the decision model.

Chapter 5 presents the use of GIS for shopping mall location selection, which is one of the core business activities of developers for long-term capital investment. In this chapter, a project is demonstrated to created features associated with household incomes, demand points, etc. Queries are then created for finding solutions for four location problems: minimum distance, maximum demands coverage, maximum incomes coverage, and optimal center. Results of this study indicate that GIS is a useful platform to support location selection decision making.

Chapter 6 presents a GIS based site selection system. This system incorporates the DEA method for real estate projects' location selection. A GIS helps users organize and combine the spatial, temporal, and economical information. The DEA method builds in the query for selecting locations by maximizing the ratio of outputs to inputs. The GIS approach is able to solve site selection problems visually, while the DEA method is argued to be objective.

Chapter 7 summarizes the major issues of this thesis. Location selection, GIS system and ANP/DEA methodology are generalized into a step procedure in investment project field. Several comments on further paths of research and practice are described.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter starts with the review of literature related to location selection. Then, relevant research efforts in shopping mall selection are discussed and summarized. The Analytical Hierarchical Network method, which has been applied in this study, is discussed. The Geographical Information System (GIS), which has been adopted in the implementation of the location selection method proposed and developed in this study, has also been reviewed.

The study of location selection has a long and extensive history spanning many general research fields including operations research (or management science), industrial engineering, geography, economics, computer science, mathematics, marketing, electrical engineering, urban planning (Drezner, 1995b).

Static and deterministic location mathematical models are the mainstream research topics in this area (Plastria, 2001), but which cannot address many of the complicated location selection problems. In consideration of changing demands over time, potential expansions, and future relocations over the long term, dynamic and stochastic models are more robust in addressing these future uncertainty issues so that the facilities built are able to remain operable over an extended time period (Owen and Daskin, 1998).

This chapter reviews the background knowledge relating to the research of location selection for construction project. The background of knowledge is accumulated through four aspects: location selection methods, the analytic network process (ANP) approach, a shopping mall location selection and GIS approach.

The understanding of location selection theory and models enable us to generate a framework for location selection for real estate development projects and to find out the suitable approach to a shopping mall location selection problem which has been used in this thesis as a case study to evaluate the location selection method developed in this study.

2.2 Location Selection Methods

The study of location theory formally began in 1909 when Alfred Weber considered how to position a single warehouse so as to minimize the total distance between it and several customers. Following this initial investigation, location theory was driven by a few applications which inspired researchers from a range of fields. Location theory gained renewed interest in 1963 with a publication by Hakimi (1963), who sought to locate switching centers in a communication network and police stations in a highway system (Owen, S.H. and Daskin, M.S., 1998). Since the mid-1960s, the study of location theory has flourished. Susan Hesse Owen and Mark S. Daskin (1998) summarized that there are three kinds of location models: static and deterministic location models, dynamic location problems and stochastic location models.

2.2.1 The Static and Deterministic Location Models

The most basic facility location problem formulations can be characterized as both static and deterministic. These problems take constants, known quantities as inputs and derive a single solution to be implemented at one point in time. The solution will be chosen according to one of many possible criteria, as selected by the decision maker (Owen, S.H. and Daskin, M.S., 1998).

The Static and deterministic location models are developed to solve four categories of problems: average travel distance problems; maximal covering problems; p-center problems; and problems with multiple objectives. The average travel distance problems are also known as the P-median problems. An important way to measure the effectiveness of a facility location in this kind of problems is by determining the average distance traveled by those who visit it (Church, R.L. and ReVelle, C., 1976). As the average travel distance increases, facility accessibility decreases, and thus the location's effectiveness decrease. This relationship holds for facilities such as libraries, schools, and emergency service centers, to which proximity is desirable.

A P-median problem (Hakimi, S.L., 1964) can be stated as follows: find the location of P facilities so as to minimize the total demand-weighted travel distance between demands and facilities. To formulate this mathematically, the following notation is used:

Input:

i=index of demand node

j=index of potential facility site

hi=demand at node i

dij=distance between demand node i and potential facility site j

P=number of facilities to be located

Decision variable:

Xj=1 if we locate at potential facility site j,

Xj=0 if not.

Yij=1 if demands at node i are served by facility at node j,

Yij=0 if not.

Using the definition, the P-median problem can be written as the following integer linear program:

Minimize $\sum hidijYij$ (1)

Subject to: $\sum Xj=P$, (2)

$\sum Yij=1 \quad \forall i$ (3)

$Yij-X \le 0, \quad \forall i, j$ (4)

$X \in 0,1 \quad \forall j$, (5)

$Yi \in 0,1 \quad \forall i, j$ (6)

Note:

Equation (1) is to minimize the total demand-weighted distance between customers and facilities. Equation (2) requires that exactly P facilities be located. Equation (3) ensures that every demand is assigned to some facility site, while constraint. Equation (4) allows assignment only to sites at which facilities have been located. Equations (5) and (6) are binary requirements for the problem variables.

In the study of developing static and deterministic models, the second category of problems includes the maximal covering problems (also known as the covering problems). Such as fire stations or ambulances which are locations for emergency service facilities. The critical nature of demands for services will dictate a maximum "acceptable" travel distances or time (Schilling et al. 1993, White and Case 1974). In the set covering problem, the objective is to minimize the cost of facility locations such that a specified level of coverage is obtained. The mathematical formulation of this type of problems can be summarized as the following:

Inputs:

Cj= fixed cost of sitting a facility at node j

S= maximum acceptable service distance (or time)

Nj= set of facility sites j within acceptable distance of node j (i.e., Nj=$\pm \{ j | d \leq S \rangle \}$)

A maximal covering problem can then be represented by the following sets:

$$\text{Minimize} \quad \sum_{j} cjXj \tag{7}$$

$$\text{Subject to:} \quad \sum_{j \in Nj} Xj \leq 1 \qquad \forall i, \tag{8}$$

$$\text{Xj} \in \{0,1\} \qquad \forall j \tag{9}$$

The objective function (7) minimizes the cost of facility location. Constraint (8) requires that all demands i have at least one facility located with the acceptable service distance. Constraints (9) require integrality for the decision variables.

The third category of problems is those related to determining a center that can maximize coverage and minimize the distance traveled (also known as P-center problems). Owen and Daskin (1998, p.429) referred to these problems as "(the minimization of) the maximum distance between any demand and its nearest facility". Thus, a P-center problem is also known as a minimal problem, as we seek to minimize the maximum distance between any demand and its nearest facility.

The forth category of problems are those problems with multiple objectives.

- For example, how to deal with multiple objectives – Many location selection problems are inherently complex in nature, which involve multiple decision objectives. For example, locating a hospital may consider both location and allocation issues, while selecting a site for a shopping mall may involve variables other than simply minimal traveling cost and maximum coverage. Generally, most of the objectives can be classified into one of the four general objective function categories suggested by Current et al. (1990), which are cost minimization, demand oriented, profit maximization, and environment concern.
- As another example, the set of fixed charge facility location problems includes problem instances which have a fixed charge associated with locating at each potential facility site. The incapacitated fixed charge facility location problem is formulated by adding a fixed cost the P-median objective function and function and removing the constraint that dictates the number of facilities to be located (Daskin, M.S., 1995).
- And the set of location-allocation problem builds upon a basic location problem formulation to simultaneously locate facilities and dictate flows between facilities and demands. These problems (as review by Scott A.J., 1970)

Combine a standard transportation problem for allocation flow between facilities with a location problem (usually a P-median problem or a fixed charge problem) for sitting the facilities.

2.2.2 Dynamic and Stochastic Models

In contrast to static and deterministic formulations, dynamic and stochastic models are mainly dealing with planning for future conditions with two core uncertainty situations: (1) planning with known model input parameters, and (2) planning with imperfect information of input parameters. They are described briefly as follows (Owen and Daskin, 1998):

Dynamic facility location models – These models usually attempt to locate facilities over a specified time horizon by formulating such real-world problems as location-allocation, spatial, and temporal aspects into either a single objective or multiple objectives with an optimal or near-optimal solution. These models assume that the future values of input parameters are known or vary deterministically over time.

In the real world, the demand is always not static, but changing. Thus, dynamic facility allocation models are to tackle problems with changing demands. Dynamic location problems can be divided into three kinds: dynamic single facility location models, dynamic multiple facility location models and alternative dynamic approaches (Owen S.H. and Daskin M.S., 1998). All these models can deal with the changing constraints inherent in location problems, and some dynamic programming formulations are given.

Stochastic location models – These models assume that future values of inputs are uncertain. It can be grouped into two approaches. Models that are developed under the probabilistic approach focus explicitly on the probability distributions of random variables, while the scenario approach embraces models that help generate a set of possible future values for the variables

2.2.3 The Discrete Location Model

In discrete location analysis the traditional criterion is usually to maximize the total net profit. The total net profit measure the gains of a certain decision, i.e. the difference between the sum of the profit of serving each client via certain facilities and the fixed cost associated with those facilities (Barros, A.I., 1998).

The optimization of this type location models, with a linear type of objective function, requires the use of classical integer programming techniques. However, in some economical applications it is also important to consider other nonlinear types of criteria, such as maximizing the profitability index. Dealing with discrete location problems with this type of criterion, where a ratio of two functions has to be optimized, requires not only the use of classical integer programming techniques but also fractional programming techniques (Barros, A.I., 1998).

2.3 Shopping Mall Location Selection

2.3.1 The Shopping Mall Location Selection

In the last two decades, retailing structures have undergone significant and sweeping changes. Technological developments and market conditions, combined with relatively affluent, highly mobile, and increasingly time-scarce consumers, have all played important roles in affecting retail changes (Anderson, 1993). As competition among regional malls increased, the design and tenant mix of shopping malls was changed to attract both retailers and consumers by a strong theme appeal to consumers' aesthetic sensibilities as well as to their functional shopping needs (Carlson, 1991). This is similar to what Burns and Warren (1995) referred to as shoppers' need for uniqueness.

Finn and Louviere (1990) found that people have a negative perception on discount department stores in quality, selection, service, and fashions as opposite to major department stores. In consequence, the existence of large shopping malls is a symbol of high quality of life.

Competition between malls and newer forms of shopping centers has led mall developers and management to consider alternative methods to build excitement with customers. Wakefield and Baker examine the relationship between three factors – tenant variety, mall environment and shopping involvement, on shoppers' excitement and desire to stay (Wakefield, K.L. and Baker, J., 1998). An important contribution of this study is the finding that two stimulus factors (mall environment and tenant variety) and one organism factor (involvement with shopping) influence excitement in a mall setting. Tenant variety has the strongest influence on excitement, followed by involvement and mall environment (Wakefield, K.L. and Baker, J., 1998).

The definition of a shopping mall is given by Wordreference (2003) as follows: A shopping mall is a mercantile establishment consisting of a carefully landscaped complex of shops representing leading merchandisers; usually including restaurants and a convenient parking area; and a modern version of the traditional marketplace.

2.3.2 Retail Chain Location Selection

We have reviewed many papers related to the marketing strategic and consumer behavior in shopping mall or shopping center. Most of the research focus is on the factors in marketing and consumer behavior. The existing literature lacks detailed discussion on shopping mall location selection criteria. From the view of project life cycle, the traditional life cycle of a project is: conceptual planning and feasibility studies, design and engineering, construction, operation and maintenance. The various sources and uses of engineering-construction knowledge are depicted in Fig.2.1. Three feedback loops from the construction project life cycle will be examined in detail.

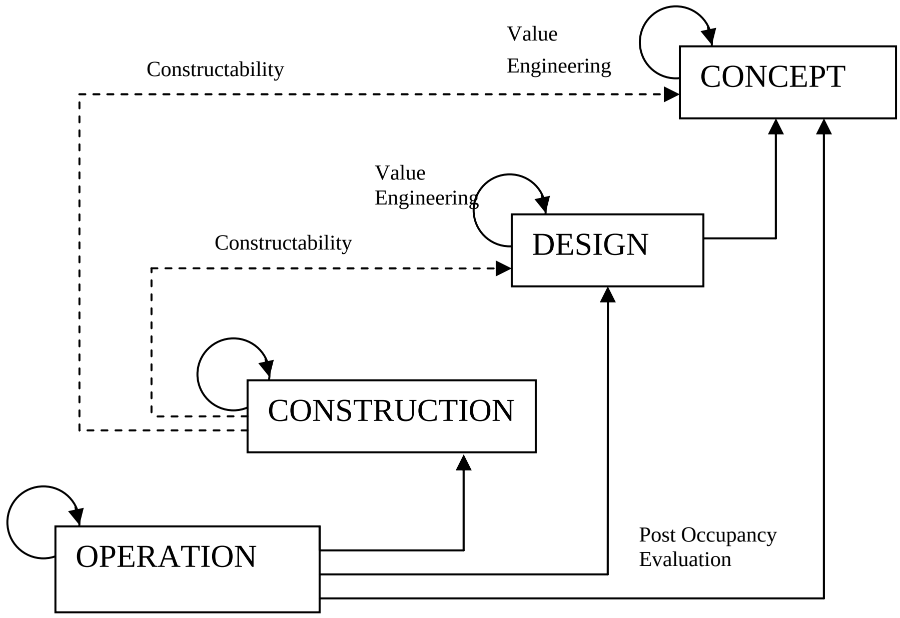


Fig.2.1 Feedback Channels in Project Life Cycle

Jones and Simmons have a mainstream location selection research in the retail environment. (Jones, k. and Simmons, A.J., 1990) The site selection process clearly differentiates the retail chain from the independent. For most independent stores, location is fixed: the business evolves to suit the site. For retail chains site selection is a continuing process – the outcome of a marketing strategy. Retail chains may use a variety of site selection techniques, ranging from a reliance on 'gut-feeling' to statistical forecasting models. In most cases store location research is undertaken in the real estate or marketing departments. There are six distinct approaches to retail site evaluation: rules of thumb, descriptive inventories, site rankings, ratios, regression models, and location-allocation procedures.

Retail location begins with lists of possible key factors, such as those shown in Table 2.1. The factors in this table have been culled from a variety of sources and divided into site and situation characteristics (Jones, k. and Simmons, A.J., 1990).

Situation:

1. The spatial extent of the market
   No. of households or population as a function of distance. (from census material, airphotos, planning studies, Zip code information.)
   Where is the outer limit (range)?
   Are there natural barriers?
2. Temporal change
   What changes in the market are forecast over the next ten years?
   How accurate is the forecast?
3. Household characteristics
   What is the household income? (from census or housing data.)
   Is it likely to change?
   Age?
   Lifestyle?
   Female participation rat
4. Competition
   How many competitors in this market?
   How far away?
5. Existing market penetration by other outlets in the chain, as indicated by credit cards, or sales slips.

Site:

6. The site constraints
   Lot size/ shape
   Zoning/ planning restrictions
   Building Condition/sales area
   Cost/ lease
   Services
7. Local access patterns
   Traffic volume, speed
   Curbs, cuts, grades
   Transit stops
   Pedestrian flow
8. Parking
   How much?
   How far?
   Shared?
9. Visibility
   Sign potential- restrictions?
   Sign clutter?
10. Nearby attractions
    Complementary stores
    Other generative land uses

Table 2.1 Site Selection: Key Factors

- ***Rules of thumb***

The location analyst, using a combination of experience, empirical observation, and trial-and-error, isolates a single key factor that appears to be directly related to sales performance, and thus store success. Some retail chains are expanding so rapidly that they have time for only the most rudimentary investigations, The Wal-Mart department store chain opens over 100 new stores per year- that's two per week (Jones, k. and Simmons, A.J., 1990).

- ***Descriptive inventories***

In this approach a list of key factors is developed, identifying the most relevant location criteria for a particular chain, and used as a framework to evaluate and select potential retail locations. Much of the early literature in retail location was based on these lists or inventories (Jones, k. and Simmons, A.J., 1990).

- ***Ranking***

Site ranking instrument provide a simple means to quantify the merits of retail locations. Site ranking schemes were developed by real estate analysts who needed quick comparisons of different sites on the basis of pre-selected criteria. These procedures are particularly common in the assessment of gasoline, fast-food, and convenience food outlets (Jones, k. and Simmons, A.J., 1990).

- ***Ratio methods***

Ratio methods are usually applied to markets (i.e. trade areas) rather than specific sites, and are based on aggregate data, often gathered by official statistical agencies. The approach may be useful for chains that serve mass markets since they can attract a fixed share of any trade area, but it may be inappropriate for chains that focus on a particular segment of the market, such as high-income neighborhoods or college students (Jones, k. and Simmons, A.J., 1990).

- ***Regression models***

The approach has become popular as access to computers and sophisticated statistical software has increased and as better spatial information systems have become available, permitting analysts to link census data and other measures of market characteristics to the firm's own indicators of performance (Jones, k. and Simmons, A.J., 1990).

- ***Location-allocation***

When the whole network of facilities is evaluated simultaneously, the analyst can turn to location-allocation techniques. These techniques can be tailored to a wide variety of specific problems, but fundamentally they are designed to allocate a given spatial distribution of demand to a specified number of outlets. Much of the research on this topic has been done in the public sector, where planners must designate service areas for fixed facilities such as school or fire stations in the most efficient fashion (Jones, k. and Simmons, A.J., 1990).

2.4 AHP in Multiple Criteria

2.4.1 Analytic Hierarchy Process (AHP): A Multiple Criteria Decision-making Tool

Vaidaya and Kumar have provided a overview of AHP application in 2004. Analytic Hierarchy Process (Saaty, T.L., 1980) is a multiple criteria decision-making tool. This is an Eigen value approach to the pair-wise comparisons. It also provides a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative performances. The scale ranges from 1/9 for 'least valued than', to 1 for 'equal', and to 9 for 'absolutely more important than' covering the entire spectrum of the comparison. There are seven key and basic steps involved in this methodology (Vaicya, O.S. and Kumar, S., 2004):

- State the problem.
- Broaden the objectives of the problem or consider all actors, objectives and its outcome.
- Identify the criteria that influence the behavior.
- Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.
- Compare each element in the corresponding level and calibrate them on the numerical scale. This require n(n-1)/2 comparisons, where n is the number of elements with the considerations that diagonal elements will simply be the reciprocals of the earlier comparisons.
- Perform calculation to find the maximum Eigen value, consistency index CI, consistency ratio CR, and normalized values; else the procedure is repeated till these values lie in a desired range.

2.4.2 Application of AHP

(Vaicya, O.S. and Kumar, S., 2004) AHP application have been classed into three groups, namely: (a) Applications based on a theme, (b) specific applications, and (c) applications combined with some other methodology. The first groups are selection, evaluation, benefit-cost analysis, allocations, planning and development, priority and ranking, and decision-making. The second groups are forecasting, medicine and related fields. The third groups are AHP application with Quality Function Deployment (QFD).

Application AHP in construction focus is on a study of construction supply chain information (Cheng, E.W. and Li, H., 2003). And AHP identify the key information may help better allocation of resources for a construction project (Cheng, W.L. and Li, H., 2001).

Application AHP in retailing location selection focus is on the convenience store (CVS) location and restaurant location (Kuo, R.J., Chi, S.C. and Kao, S.S., 2002) (Tzeng, G.H. el., 2002)

For selection convenience store location, a decision support system for location a new CVS Such as 7-ELEVEN. The proposed system consists of four components: (a) hierarchical structure development for fuzzy analytic hierarchy process (Fuzzy AHP), (b) weights determination, (c) data collection, and (d) decision making. Finally, a feedforward neural network with error back- propagation (EBP) learning algorithm is applied to study the relationship between the factors and the store performance (Kuo, R.J., Chi, S.C. and Kao, S.S., 2002).

For a restaurant location, there are five aspects and 11 criteria are used to develop a location evaluation hierarchy for a restaurant. The criteria are rent cost, transportation cost, convenience to mass transportation system, size of parking space, pedestrian volume, number of competitors, the intensity of competition, size of the commercial area where the restaurant is located, extent of public facilities, convenience of garbage disposal, and sewage capacity (Tzeng, G.H. el., 2002).

2.4.3 AHP Hierarchical Structure Development for the Location Selection

The AHP is one of the extensively used multi-criteria decision-making (MCDM) methods (Bagranoff, N.A., 1989) (Arbel, A.and Orgler, Y.E., 1990) (Moutinho, L., 1993).One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pair-wise comparisons, and priority vector generation and synthesis (Saaty, T.L., 1980). Though the purpose of AHP is to capture the experts' knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, Laarhoven and Pedrycz (Laarhoven, P.J.M. and Pedrycz, W., 1983) first applied fuzzy sets theory (Zadeh, L.A., 1965) (Zimmermann, H.J., 1991)AHP in order to solve the objective, uncertain and fuzzy questions. In addition, Buckley (Buckley, J.J., 1985) also presented a similar approach.

A decision support system for location a new CVS consists of four components: hierarchical structure development for fuzzy analytic hierarchy process (fuzzy AHP), weights determination, data collection, decision making. (in figure 2.2)(Kuo,R.J. and Kao,S.S., 2002).

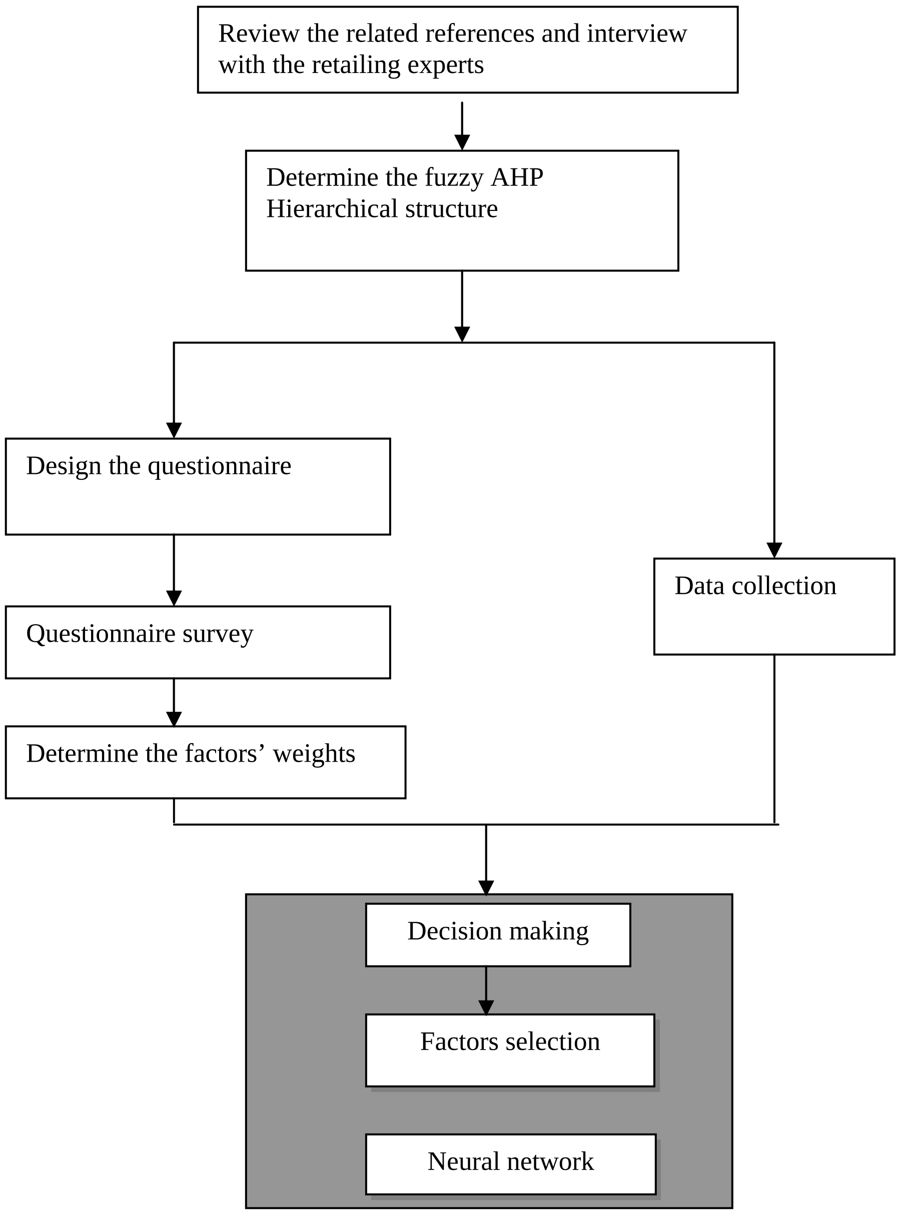


Figure: 2.2 the Intelligent Decision Support System Location a CVS.

References to above all literatures and discover there is little literature to research shopping mall using AHP in retailing. This dissertation will go on discussing the problem.

2.5 The Application of GIS

2.5.1 The Background of GIS

The geographic information systems (GIS) technology is appropriate for a variety of usages including resource management, land surveying, and business planning. For example, a GIS might allow planners to create maps for specific use, while another GIS might be able to determine the size of wetlands necessary to be protected against damages and pollution from new district development.

By definition, a GIS is a computer system capable of assembling, storing, manipulating, analyzing, and displaying geographically referenced information (i.e. data identified according to their locations) (USGS, 2002). It makes use of digital mapping technology to provide options for decisions. Practitioners are increasingly relying on the total GIS solution since there were commercial vendors providing the GIS technology.

A GIS supersedes other information systems by enabling the handling of both spatial and non-spatial data, leading to its authoritative roles in data management and integration, data query and analysis, and data visualization (Li et al., 2003). It combines spatial and non-spatial data to construct thematic maps for communicating complex geographic information that cannot be worked in table or list forms (GIS, 2003).

The way that maps and other data have been stored or filed as layers of information in a GIS makes it possible to perform complex analyses. Even if image data that have already been converted from research to digital form are not available, a GIS can produce digital maps by incorporating spatial data. Tabular data, such as shoppers' behavior obtained by means of surveys, are then entered into it to act as the information for different layers.

Figure 2.3 exhibits a multi-layer architecture of a GIS, which is adapted from Li et al. (2003). Each of these layers represents a single theme in a region comprising similar features such as customers, streets, buildings, etc. Li et al. (2003) described the functions of a GIS. Specifically, a GIS adopts database management systems to establish its own data indexing system, in which queries (commands) can be undertaken by retrieving values of stored data. Data are stored in physical storage devices according to their locations in space and are managed using numerical or alphabetical order. For example, it can help locate hospitals within 5 km or within 30 minutes drive from a center point. Moreover, the separate layers are connected by a coordinate system so that data from different layers can be combined to form the information that matches the query for obtaining optimal solutions.

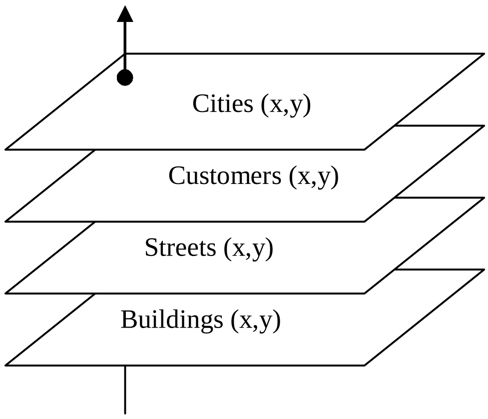
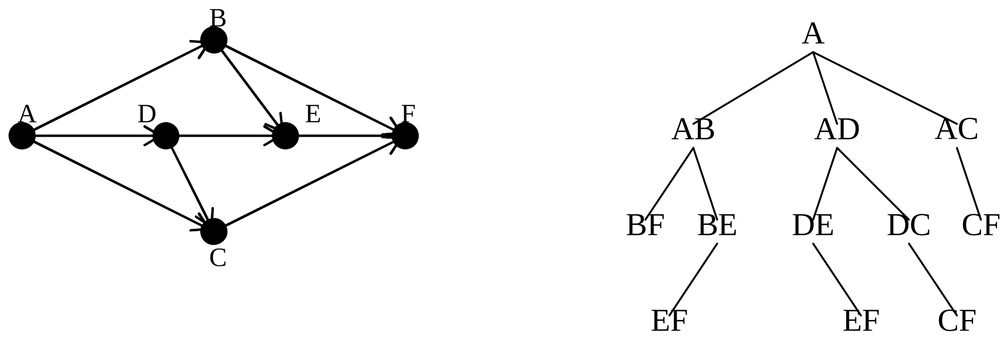


Figure 2.3 A multi-layer architecture of a GIS

The architecture of the GIS is developed based on the concept of network. A network is defined as a set of points (known as nodes) and a set of arcs where each branch connects a pair of nodes. Figure 2.4 exhibits the concept of network as adapted from Li et al. (2003) but explains in a clearer way. Figure 2.4 (a) exhibits a simple network of distance traveling, consisting of six nodes (denoted by uppercase letters A, B, C, D, E, and F) and nine arcs (not to scale) (denoted by two uppercase letters, such as AB, BE, DC, etc.). A path in a network is a sequence of connected arcs on condition that no node is repeated. Figure 2.4 (b) construct a tree structure, which is formed by the five paths being A-B-F, A-B-E-F, A-D-E-F, A-D-C-F, and A-C-F. If the exact distance in each arc is known, it is able to calculate the total distance for each of the five paths. The GIS will help determine which is the shortest path from A to F by: (1) locating the nodes in a map, (2) measuring the distance of each arc, (3) measuring the distance of each path by combining the distances of the connected arcs for each path, and (4) comparing the paths to find the shortest path.



(a) (b)

Figure 2.4 (a) Nodes and arcs of a network

Figure 2.4 (b) Paths as shown in a tree structure

According to the U.S. Geological Survey (2002), there are eight functional components of a GIS, which are described below:

Using data from various sources – A GIS can use and relate data generated from various sources about a location to generate useful information for queries. Location is generally annotated by use of coordinates (x, y, and z) of latitude, longitude, and elevation. Such systems as Zip codes or highway mile makers can also be used for the annotation of location. In order to feed into a GIS, the primary concern is that the source data can be located spatially. Likewise, a GIS can convert existing digital information or census or hydrologic tabular data into map-like form, producing layers of thematic information in a GIS.

Data capture – A GIS can only use data in digital form (i.e., a form that is recognized by the computer). Therefore, all the data not in digital form must first be digitized. For example, a map can be digitized to enable the feature of coordinates. There are many techniques that can capture the data. For example, electronic scanning devices can help covert map lines and points to digits. However, data capture is time-consuming. It is further noted that during the process of data capture, identities of the objects on the map must be specified clearly.

Data integration – A GIS is able to link and integrate various kinds of data. Specifically, a GIS combines mapped variables to build and analyze new variables. For example, if a GIS has such data as roads and traffic accidents, it is possible to generate information about which roads have more accidents. The police station is able to use the information to formulate policy (e.g., implementation of road block or installation of traffic lights) to improve road safety. To integrate geographic data, a GIS makes use of an automated process (namely geocoding) to tying implicit references (e.g., a street name, a building name) to explicit geographic references (i.e., a specific point on a map with latitude and longitude coordinates) (GIS, 2003).

Graphic display techniques – Dissimilar to traditional maps (using symbols to represent physical objects) or topographic maps (using contour lines to represent the shape of land surface), graphic display techniques make associations among map elements visible, heightening the ability to extract and analyze information. In a GIS, the two types of map data are combined to produce a perspective view, where a digital elevation model is formed to present surface elevations by assigning high elevations and low elevations in different colors.

Projection conversions – Before the digital data can be analyzed, they may need to undergo projection conversions. Projection being a fundamental component of mapmaking is a mathematical means of manipulating map data. This includes the transformation from the three-dimensional real world to a two-dimensional illustration in computer screen and research forms. Since much of the information in a GIS comes from existing maps, distortion is commonly encountered. For example, distortion would happen when producing a rectangular shape of the world map from a physically sphere-shaped Earth's surface.

Data structure – Data may be of different structures. This is due to the use of different ways to collect and store digital data. Various data structures may be incompatible. Therefore, a GIS would convert (restructure) data from individual structures to compatible structures (formats).

Data modeling **–** There are two types of data models (vector and raster). The former presents discrete features, while the latter presents continuous numeric values (GIS, 2003). Raster data files are useful for producing land use maps, while vector data files can approximate the shape of hand-drafted maps as they can capture the digital data as points, lines (a series of point coordinates), and areas (shapes bounded by lines). In order to produce lines around all cells with the same classification in a vector structure, the cell spatial relationships (e.g., adjacency or inclusion) must be determined.

Data output **–** After a GIS is produced, the layers can be shown as graphics on the computer screen or be printed on research. Its expanded power allows queries to be set to convey results that are appropriate for making decisions. A final note is that a GIS can generate wall maps and other graphics, allowing users to visualize and simulate the potential solutions.

2.5.2 GIS and Location selection

Since the 1970s the field of Geographical Information System (GIS) has evolved into a mature research and application area involving a number of academic fields including Geography, Civil Engineering, Computer Science, Land Use Planning, and Environmental Science. GIS can support a wide range of spatial queries that can be used to support location studies. GIS will play a significant role in future location model development and application (Church, R.L., 2002).

Geographical Information Systems involve software that provides storage, retrieval, analysis, visualization, and mapping capabilities for spatial data such as road networks, land use information, census track data, etc. Some GISs include embedded location models and most and most provide the opportunity to integrate location model within a map-based graphical user interface. Because GIS can be used to assemble data from various sources involving different map scales and transformations, it can be a significant aid to the location analyst. Firs, some of the software features support needed for operations in a location model application. Second, a growing data development industry supported primarily by GIS users now makes or packages a number of data products which could have significant value in location studies. Third, GIS software often uses state-of-the-art databases engines and is designed to handle large volumes of data (Church, R.L., 2002).

Although such site searches seem simple, and they are, they do support the bulk of the site selection problems in industry and commerce. More sophisticated search procedures have been applied in a GIS or spatial decision support context (Kao,J-J,el., 1996) (Arentze, TA.el., 1996). Carver (Carver,SJ., 1991) has integrated a mulit-criteria approach with GIS for suitability analysis. Mark et al. (Marks AP., ei., 1992), Goodchild (Goodchild MF., 1991), Birken (Birken, M., 1996), and Longley and Clarke (Longely, P. and Clarke, G., 1995), their paper deals with the potential siting of hospitals to provide cost-effective health care. Their approach utilized a number of siting criteria for ranking potential sites. They included existing facilities and their capacities, distances to other facilities and metropolitan areas, percent of population older than age 65, existing land use, site availability, percent slope, and the availability of existing infrastructure services such as water and sewer (Church, R.L., 2002).

Not only can the GIS serve as the source of input data for a location model, it can also be used to present model results. It is not difficult to export data from a GIS support a location model, solve a location model using special purpose software, and then import the results back to the GIS for mapping and display. Such GIS display systems as ARC/View can be used to present results that have either been generated within the ARC/Info GIS or imported to ARC/Info. Several GISs are available which allow the development of a customized application and display. For example, the MapInfo system makes it very easy to apply to a location study, especially for retail or service site selection. An interesting example of the use of MapInfo in a location study has been presented by Camm et al. (Camm, JD. El., 1997)

Environmental Science Research Institute (ESRI) has made it possible to heuristically solve p-median problems and display solutions using a GIS. TRANSCAD also provides the capability of solving location problems with GIS plus. It is reasonable to expect that other systems will emerge in the near term that will provide this capability as will. And the ARC/INFO system with the network module readily solves such problems as the maximal covering location problem and the attendance-maximizing problem (Church, R.L., 2002).

GIS and location models will be linked for model applications. Linking GIS and models requires that a number of technical and basic research issues be addressed (Church, RL. and Sorensen, P., 1996). There are six major categories of integration and linking factors.

- Problem scale and representation.
- Error propagation.
- New models.
- Better algorithms and heuristics are needed.
- Interface development.
- Data structures

(Church, R.L., 2002)

There are Benoit and Clarke, Murad research the creating a GIS application for retail location. Benoit and Clarke evaluates the use of proprietary GIS for retail location planning and address the appropriateness of simple functions such as mapping, overlay and 'buffer and overlay', which have been used in many examples of retail planning (Benoit, D. and Clarke, G.P., 1997). Murad discusses the created GIS application that is designed for two retail centers in Jeddah city, Saudi Arabia. Two useful models have been produced by this study. One is called marked penetration and the other is based on spatial interaction technique. The former is created to examine retail center catchment area, while the latter is used to model the interaction between demand areas and retail centers (Murad, A.A., 2003).

2.6 Conclusions

In this review, we have attempted to provide an overview of location selection methods, shopping mall location selection, AHP and location selection, GIS and location selection to dedicate to how to apply a research method to research the problem of investment project location selection. I hope the shopping mall is a case study.

Location selection methods are divided into two kinds: static and deterministic location selection models, Dynamic and stochastic models. Another main location selection model is discrete location models. It may be static or dynamic models. Shopping mall location selection research has closed relationship with retail location selection. But most shopping mall research focuses on the marketing and consumer behavior. The retail location selection has many possible key factors. It is divided into site and situation characteristics.

AHP is a multiple-criteria decision making tool. About the retailing location selection, we find out the research focus on the convenience store and restaurant location. There is not a shopping mall location selection using AHP. GIS play a important role in location model development and application.

We expect research to continue in this direction. Specifically, we look for better methods to relate the shopping mall location selection, AHP and GIS. It is make the investment decision maker make a clear and directly decision in a short time.

CHAPTER 3: EXPLORATION OF LOCATION SELECTION METHODS FOR FIXED INVESTMENT IN THE CONSTRUCTION FIELD

This research aims at exploring the location selection methods that are appropriate for fixed investment in the construction field. One of the major considerations of whether to undertake a construction project is to determine if the location is valuable for investment. Location selection may be simply based on past experience, rudimentary, “gut-feeling”, or a combination of them. Alternatively, it may involve scientific methods. The research introduces both deterministic and dynamic approaches and presents some of the basic quantitative methods, including data envelopment analysis model and binary integer linear program models, serving as a base for both academics and practitioners. To expand the contribution of the research, illustrative examples are provided.

3.1 Introduction

Each developer (private or public) is always involved in selecting a location or a site for its long-term fixed investment. An invested project may be a commercial building, a hotel, a bridge, etc. In the construction field, however, there is a paucity of literature discussing about how to select a location for investment. It is understood that popular methods used in location selection are simply based on “gut-feeling”, past experience, rudimentary investigations or a combination of them.

Selecting a location for fixed investment is perhaps the single most critical decision a developer has to make. The better the location, the more is its return on investment.

Conversely, worse location would lead to a low profit margin or be even detrimental to the survival of the company in this extremely competitive environment.

Before a developer selects a location for investment, it must first determine what project has to be undertaken. Different undertakings depend on different requirements (Owen and Daskin, 1998). For example, factory location problems may involve a different set of criteria or objectives when compared with shopping mall location problems.

Given the extensive development in location selection models in different fields, this research aims at exploring the application of mathematical models in solving location selection problems for construction projects. The rest of the research consists of two core components. First, it reviews the existing key literature on location selection, attempting to lay a foundation for future research. Second, it presents the location selection methods lying within operations research for fixed construction project investment. In order to expand the contribution of the research, examples of retail location selection are demonstrated by use of mathematical models.

3.2 Location Selection in General

The existing literature in the construction field does not indicate a systematic fashion of location selection research. However, the study of location selection has a long and extensive history spanning many general research fields including operations research (or management science), industrial engineering, geography, economics, computer science, mathematics, marketing, electrical engineering, urban planning (Drezner, 1995b). Various terms (e.g., facility location selection, store choice, and site selection) are being used for location selection, but they bear different meanings. For example, facility location problems are solved to minimize the total cost of serving all customers (e.g. a service center). Retail location problems, on the other hand, center on how to identify a location that can maximize the number of shoppers.

A rich source of seminal researches can be found from the field of location science, which regards location selection problems as geometrical and combinatorial optimization problems. Owen and Daskin (1998) attributed a large amount of facility location selection studies to operations research. A number of mathematical programming models have been developed, which can be classified as (1) static and deterministic models, and (2) dynamic and stochastic models. Current et al. (1990), on the other hand, reviewed that facility location are selected on the basis of four broad categories of objectives (i.e., cost minimization, demand-orientation, profit maximization, and environmental concerns).

Static and deterministic location mathematical models are the mainstream research topics in this area (Plastria, 2001), but which cannot address many of the complicated location selection problems. In consideration of changing demands over time, potential expansions, and future relocations over the long term, dynamic and stochastic models are more robust in addressing these future uncertainty issues so that the facilities built are able to remain operable over an extended time period (Owen and Daskin, 1998).

According to Owen and Daskin (1998), static and deterministic models have five basic purposes, which focus on:

- . For example, schools, retail shops, and emergency service centers must be near to target residents, and thus proximity is desirable for a wide range of public and private facilities.

- How to achieve maximum coverage – With respect to facilities such as police stations, fire stations, community centers, and hospitals, the most crucial is about how to determine the minimum number of facilities needed to cover all demands, given that they can serve within an acceptable time. Such a cost minimization to save available resources is usually a policy for locating public facilities.

- How to determine a center that can maximize coverage and minimize the distance traveled. Owen and Daskin (1998, p.429) referred to this as "(the minimization of) the maximum distance between any demand and its nearest facility". This type of regret models considers opposing problems in terms of distance and coverage in locating a center for building a facility.

- How to deal with multiple objectives – Many location selection problems are inherently complex in nature, which involve multiple decision objectives. For example, locating a hospital may consider both location and allocation issues, while selecting a site for a shopping mall may involve variables other than simply minimal traveling cost and maximum coverage. Generally, most of the objectives can be classified into one of the four general objective function categories suggested by Current et al. (1990), which are cost, demand, profit, and environment.

- How to locate undesirable facility – Apart from the selection of desirable facilities location, there are practical applications dealing with locating undesirable facilities that should be located away from populations, such as waste disposal plants, airports, water treatment centers, and nuclear plants.

In contrast to static and deterministic formulations, dynamic and stochastic models are mainly dealing with planning for future conditions with two core uncertainty situations: (1) planning with known model input parameters, and (2) planning with imperfect information of input parameters. They are described briefly as follows (Owen and Daskin, 1998):

Dynamic facility location models **–** These models usually attempt to locate facilities over a specified time horizon by formulating such real-world problems as location-allocation, spatial, and temporal aspects into either a single objective or multiple objectives with an optimal or near-optimal solution. These models assume that the future values of input parameters are known or vary deterministically over time.

Stochastic location models **–** These models assume that future values of inputs are uncertain. It can be grouped into two approaches. Models that are developed under the probabilistic approach focus explicitly on the probability distributions of random variables, while the scenario approach embraces models that help generate a set of possible future values for the variables.

3.3 Location Selection in Construction and Real Estate

3.3.1 Location Selection for a Construction Project

Apart from classifying location selection projects as private or public (Daskin et al., 1997), it is also suggested that location analysis is of two kinds: (1) potential locations restricted to a single area (e.g., a single city), and (2) potential locations spread-out over a number of areas (e.g., cities of different states or even cities of different nations). In general, the same methods can be used to solve the problems of both kinds but they normally involve different sets of variables and specific mathematical formulation. As Current et al. (1990, p.296) stated, "Location problems are often uniquely defined by their particular problem setting. Both the constraints and objective function will vary by application". To reduce the size of the research, this study focuses on the first kind, referring to fixed investment in a single city to reduce the complexity of analysis due to differences in such factors as spatial distributions, cultures, tastes, etc.

Furthermore, project investment can be grouped into four clusters in terms of the amount of investment for each project and the project types. Figure 3.1 illustrates the four clusters of project investment. The horizontal arrow refers to the amount of investment for a single project, while the vertical arrow refers to two project types (independent project or chain business). A small investment for an independent project is common for most investors, especially small retailers. Examples of a large investment for a single project include building projects (commercial, residential, or industrial) or infrastructure projects. An investment project for a chain business (mainly retail chain business) is the location selection for a single outlet, which may entail a small or a large amount of investment.

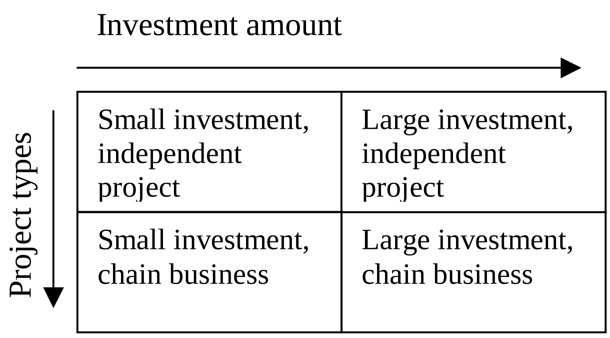


Figure 3.1 Four clusters of project investment

Location selection is different from one project to another. For example, a chain business may need a fast decision, while an independent project looks for more detailed analysis. A retailer finds a location for running a retail business, while a developer invests in constructing a commercial building for rental purpose. Different projects are expected to entail different methods for location selection. This research attempts to deal with problems on retail location selection. Berry et al. (1988) argued that research in retailing has a mature analysis of location selection for stores and shopping centers. As suggested by Jones and Simmons (1990), most of the retail problems are related to spatial matters so that existing spatial theories and models are developed involving the use of maps, trade area analysis, and regression techniques.

3.3.2 Location Selection for Independent Projects

Independent projects are referred to as one-off projects. With respect to location selection, independent projects rely on the attractiveness of a single site (Jones and Simmons, 1990) rather than their linkage to previous or future projects in terms of the project type and project size (dissimilar to retail chain business). Independents incur either small or large investment. Examples of small investment projects are small retailers, such as a specialized French restaurant, a local boutique, etc. Examples of large investment projects include a shopping mall, a commercial building, a residential estate, a fee-paying tunnel, etc.

Unlike retail chains (which are discussed in the following section), independents look for more precise site selection because they target on a single investment for a medium or long-term purpose. Plainly, small retailers are expected to use less sophisticated methods since their location selection depends on a small number of key factors. Whereas, large projects are more complicated and should take more key factors into account.

Using a small number of key factors to select a site is sometimes called the descriptive inventory (Jones and Simmons, 1990). Different projects in terms of their business types or even their marketing strategies of the same business type deserve different sets of key factors, which form the basis for quantitative assessment. The widely used quantitative methods are rating and ratios.

Simple linear rating methods have been widely used because it is simple and is fast to make decision. The simplest formula is: $\sum Ci$ where Ci is the criterion i. Using objective measures or developing a scale for measuring these criteria and then adding the scores for all criteria to calculate the total score. If there is only a single site being under consideration, we can set a minimum scored value determined by experience, hunch, etc. If the total score exceeds this minimum value, the site will be considered for acquisition. If there are several potential sites, the one with the highest score will be intentionally selected. Sometimes, an average score can be calculated [i.e., $(\sum Ci) / n$ where n is the number of criteria], and the interpretation is the same as above.

The above example assumes that criteria are equally important. In reality, criteria may have different levels of criticality. This involves assigning weight to each criterion. A general formula that calculates the total score is $\sum WiCi$ (where Wi is the weight assigned to the criterion i). For calculating an average score, the formula $[(\sum WiCi) / n]$ can be used. There are many methods to determine the weight for each criterion, such as regression models, MCDM (multi-criteria decision-making), etc. Molenaar and Songer (1998) used the regression model for public sector design-build project selection. Their regression model (p.468) is expressed below:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \ldots + \beta_{K-1} X_{i,K-1} + \varepsilon$$

(Where Y_i = the dependent variable i; β_0 to β_{K-1} = constant or regression coefficients; X_1 to X_{K-1} = the independent variables; ε = error term; i = index of the individual cases; and K = number of parameters)

In the above linear mathematical model, the independent variables are the criteria, while the regression coefficients correspond to the weights assigned to the criteria. For the method of MCDM, refer to the textbook of Saaty (1980) or other application research (e.g., Cheng and Li, 2002).

A simple example to illustrate the linear rating method is used. Suppose that a retailer would like to open an outlet in a shopping complex and it has several locations (i.e., several shopping complexes) on hand for selection. It would like to make the decision based on such two common criteria as the number of households in the area (C_1) and the average monthly spending in that shopping complex (C_2). The larger the number of households, the greater the expectation that people living nearby would go to the shopping complex. The more the average spending in the shopping complex, the better the chance that goods and services can be sold. Such data are normally obtained from the management company of each of the shopping complexes. If the retailer thinks that these two criteria are equally important, it may simply use the rating method to calculate a total score from the scores to the two criteria. Table 3.1 exhibits the results. The total score indicates that two of the shopping complexes have the same highest score. Thus, such information is too vague to make a decision.

As stated earlier, a more precise way is to assign weights to the criteria. In Table 3.1, the two criteria are assigned of weights so that the weight of C_1 is 0.2, while that of C_2 is 0.8. That is, C_2 is four times more important than C_1. The total non-weighted scores indicate that Shopping Complex 5 is the best location since it has the largest score. Yet, if the criteria are equally important, the weight information has no effect on facilitating the decision to be made. It is not the purpose of this research to discuss in greater depth these weighting methods. For more details, refer to methodology textbooks (e.g., Hair et al., 1998; Saaty, 1980).

Other than rating, non-linear ratio methods are also used in location selection. Ratio helps to analyze the relationship between two variables. Sometimes, a non-linear relationship exists among criteria. Using back the above rating example, suppose that for a more accurate account of the performance of a shopping complex, it is crucial to calculate the average monthly spending per capita. In other words, this requires the calculation of the ratio of the average monthly spending in a shopping complex to the number of households in that area. The ratio scores exhibited in Table 3.1 show that Shopping Complex 2 is the best place to open an outlet. Further accounts can be elaborated. For example, Shopping Complex 3 is more attractive than Shopping Complex 5 although the latter has a larger number of households in the area than the former. In addition, Shopping Complex 5 is more attractive than Shopping Complex 4 because the average spending in the former is much higher than the latter although they have the same number of households in the area.

Table 3.1 Comparing rating and ratio methods

	Shopping Complex 1	Shopping Complex 2	Shopping Complex 3	Shopping Complex 4	Shopping Complex 5
The number of households (C_1)	3 (25000)	2 (15000)	3 (25000)	5 (45000)	5(45000)
The average monthly spending (C_2)	3 (5m)	5 (9m)	4 (7m)	1 (1m)	3 (5m)
Total non-weighted score ($C_1 + C_2$)	6	7	7	6	8
Total weighted score	3	4.4	3.8	1.8	3.4
Ratio value	200	600	280	22	111

Note: (1) The scale for measuring the number of households (C_1) is: 1 = equal to or less than 10000, 2 = 10001 to 20000, 3 = 20001 to 30000, 4 = 30001 to 40000, and 5 = more than 40000. (2) The scale for measuring the average monthly spending (C_2) is: 1 = equal to or less than 2m, 2 = 2m+1 to 4m, 3 = 4m+1 to 6m, 4 = 6m+1 to 8m, and 5 = more than 8m (where m = million dollars). (3) Weight to C_1 is 0.2, while weight to C_2 is 0.8. (4) Ratio value = Average monthly spending / number of households.

The function of the non-linear ratio method can be expanded to incorporate more inputs and outputs in a data envelopment analysis (DEA) model. There are many studies adopting DEA (e.g., Cook and Green, 2000; Joro et al., 1998). In this research, we present a simplified model for the previous example that is to locate the best performing shopping complex for a new retail shop. The problem can be formulated as follows:

Inputs:

The number of households in the area

The number of shopping complex in the area

Outputs:

The average monthly spending in the targeted shopping complex

Average disposable income in the area (monthly)

Savings of households in the area (monthly)

Mathematical model:

$P_i = \sum (w_k y_{ik}) / \sum (w_j x_{ij})$ (1)

Objective (1):

To decide the optimal performance of each of the five shopping complexes by maximizes P_i subject to the constraints stated below.

Where:

i = the index of the potential locations

j = the index of the inputs

k = the index of the outputs

x_{ij} = input j for the location i;

y_{ik} = output k for the location i;

w_j = the weight assigned to the input j;

w_k = the weight assigned to the output k; and

P_i is the performance of Shopping Complex i (expressed as a fraction).

Subject to:

$0 <= P_i <= 1 \quad \forall i,$ (2)

$x_{ij}, y_{ik}, w_k, w_j >= 0 \quad \forall j,k.$ (3)

Constraint (2) states that the performance value of i must be nonnegative and must not exceed one. Constraint (3) states that the variables must be nonnegative.

Other assignment constraints can be added if they are appropriate for obtaining a solution. The above non-linear model can be easily transformed to a linear programming model for computation once data of the variables x_j and y_k are available. For example, to calculate the performance of Shopping Complex 1, it is essential to set an equation: $\sum(w_j x_{1j}) = 1$ where j = 1,2 and solve for all weights (w_j and w_k). Then, the performance of Shopping Complex 1 can be calculated using the equation $P_1 = \sum(w_k y_{1k})/\sum(w_j x_{1j})$. After calculating the performance for all shopping complexes, it is then easy to select the best performer by comparing their P values, which should be the best place for locating a new outlet. An illustrative example is exhibited in Appendix 1.

If the problem involves a linear function and requires a binary decision, it is customary to use integer linear program model. An example is shown in later section.

3.4 Location Selection in Retail Chain Business

Retail is one of the main marketing activities in the community and provides goods and services to the domestic consumers. Location selection for a retail outlet is a very ordinary task and is frequently undertaken. Retail chains refer to many identical (or almost identical) retail outlets opened in different locations of an area. These outlets use the same name (e.g., McDonald’s, Citibank) and sell the same kind of goods or services. For retail chains, site selection entails a continuing process that regulates by the marketing strategy. Nowadays, there are many kinds of goods and services forming retail chains including restaurants, gift shops, convenience stores, supermarkets, banks, department stores, oil stations, fashion retails, record stores, cake shops, grocery business, etc.

Although various types of retail chains have their own rates of expansion of their outlets, they are generally characterized by (1) their ability to increase market share by use of more outlets, (2) their confidence of weeding out non-profitable outlets, (3) their target markets that are clearly flexible, and (4) for certain types, their relative insensitive to location (Jones and Simmons, 1990). Another characteristic of them is that they need to respond rapidly to locations offered in the market to get rid of their business competitors as well as other location hunters.

Due to the necessity of fast decisions to location selection, small to medium-sized retail chains (e.g., cake shops, fast food business) are fond of using *rules of thumb*, which aim at identifying the most important factor by using a combination of experience (i.e., trial-and-error), hunch, empirical observation, and some rudimentary calculations (Jones and Simmons, 1990). For example, sales performance usually appears to be directly associated with a good location and is expected to be a reliable indicator. It is then reasonable to set the location objective to maximizing sales performance. Hence, the advantages of this method are that it permits quick decisions and incurs a very low cost for analysis.

As previously noted, retail chain can be business with either small or large outlets. For example, the famous 24-hour convenience store, 7-Eleven, opens small outlets when compared with those large outlets of the well-known brands WalMart and Marks & Spencer. Table 3.2 exhibits some examples of the common locations and key factors for retail chain business in Hong Kong.

In a crowded city, like Hong Kong, retail chain business is everywhere. The government's town planning department shapes the city into different districts with similar population size despite a handful of individual characteristics in terms of household income, age, lifestyle, and family size that fairly differentiates one district from another. In the case of Hong Kong, such marketing factors as the number of households in a trade area, the number of credit card holders in a trade area, and trade area income composition might be less important in key commercial and shopping areas since it is assumed that there is perfect mobility of people. Therefore, chain retailers would simply consider if it is a commercial or residential area, whether the location is convenient to consumers, and whether it is a busy area (usually a shopping area). Other key factors may be nearby rivals, adjoining complementary business, and landscapes. The abovementioned marketing factors are related to allocation problems and are linked to the overall business strategy of the company, such as how many outlets should be open in the city and how to allocate these outlets.

Table 3.2 Examples of the key factors for retail chain business in Hong Kong

Retail chain business	**Common location**	**Key specific factor**
Supermarkets	Mainly in residential areas	Easy to access; car-parks
Convenience stores	Everywhere	Easy to access
Department stores	Commercial areas	Busy areas; shopping malls
Fashion	Commercial areas	Busy areas; shopping malls
Fast food business	Everywhere	Easy to access; busy areas
Banks	Everywhere but not as many as fast food outlets or convenience stores	Safety areas; busy areas
Oil stations	Major roads	Heavy road demanding
Gift shops	Commercial areas	Busy areas; shopping malls
Groceries	Mainly residential areas	Busy areas; shopping malls
Cake shops	Everywhere	Busy areas
Restaurants	Commercial and residential areas	Fewer competitors in residential areas; form a restaurant zone with competitors in commercial areas
Service centers	Commercial areas	Minimum rental fees

The rule of thumb (or one-factor) strategy can be expanded to consider more than one variable or objective. The multi-variable or multi-objective principle is particularly useful for large or medium-sized retailers (e.g., department stores and supermarkets), and the problems can be transformed to an integer linear program model. The most popular models mainly deal with attraction to a facility. In terms of retailing, attraction is the demand raised for a good or service that the retailer provides. A new retail shop is profitable when it is able to transfer the current attraction to its attraction. Obviously, attraction is a decreasing function of distance between a demand point and a retail shop. Demand points can be discrete or continuous. Plastria (2001) refers to continuous spatial distribution as regional demand, which is assumed to be uniform and is associated with a continuous or network environment. In reality, demand is supposed to be continuously distributed in an area. Models of split demand have been widely published (e.g., Okabe and Suzuki, 1997; Hakimi et al., 1992).

For simplicity, an example that is going to present assumes known discrete demand points. Popular discrete models are developed to solve median and covering problems to locate facilities that can achieve the objectives such as to maximize the expanded new customers or captured or increased market share (Owen and Daskin, 1998). An example model was supplied by ReVelle (1986, p.349), which is used for multi-objective maximal coverage and is shown below:

Maximize $[\sum a_i y_i + \sum (a_i/2) z_i, \sum b_i y_i + \sum (b_i/2) z_i]$

(Where yi = 1,0; 1 if node i gets a new server, zi = 1,0; 1 if node i is captured by a server, ai = population at demand node i, and bi = assessed valuation at demand node i)

In the current example, it is supposed that a chain retailer (e.g., a department store chain) would like to expand its business by locating a new site from several potential sites for a new store. It focused on two major objectives: among the potential sites, the target site must (1) be the easiest to access and (2) cover the busiest area.

Accessibility is a decreasing function of travel distance (Owen and Daskin, 1998). More specifically, the larger the average travel distance, the lower is the level of accessibility, resulting in less effective target location. Moreover, it is anticipated that the busiest area should possess maximal demand points and is therefore a key variable for location selection. This is based on the presumption that consumers always patronize the closest facility (Hotelling, 1929; c.f. Drezner and Drezner, 1998). Maximizing the coverage of potential consumers would lead to more effective target location. When considering maximal capture, it is necessary to take the existing stores that were already patronized (i.e., current competitors in the enclosed area) into account. Both objectives are set to select a site with maximal attraction. This attraction problem urges optimization in such a way to achieve highest profit margin. Having described the problem verbally, we can formulate the problem mathematically as follows (adapted from Plastria, 2001; ReVelle, 1986):

Objectives:

Minimize $\sum_i \sum_j d_{ij}u_{ij}$ (4)

Maximize $\sum_j g_j y_j + \sum_j g_j z_j / 2$ (5)

Subject to:

$\sum x_i = 1$ $\forall i,$ (6)

$\sum u_{ij} = 1$ $\forall i,j,$ (7)

$u_{ij} \leq x_i$ $\forall i,j,$ (8)

$y_j \leq \sum x_i$ $\forall i,j\ (j \in m_j),$ (9)

$z_j \leq \sum x_i$ $\forall i,j\ (j \in n_j),$ (10)

$y_j + z_j \leq 1$ $\forall j,$ (11)

$x_i \in \{0,1\}$ $\forall i,$ (12)

$u_{ij} \in \{0,1\}$ $\forall i,j,$ (13)

$y_j, z_j \in \{0,1\}$ $\forall j.$ (14)

Where:

i = the index of a potential location (potential department store);

j = the index of a demand node;

x_i = 1,0; 1 if a potential department store is intended to locate at i;

u_{ij} = 1,0; 1 if demands at node j are served by a potential location at node i;

g_j = demand at node j;

d_{ij} = distance between potential location i and demand node j;

y_j = 1,0; 1 if demands at node j are fully captured;

z_j = 1,0; 1 if demands at node j are tied with a competitor;

m_j = Demands at node j can patronize the location i;

n_j = A tie between a competitor and the location i with demands at node j.

The objective function (4) is to minimize the distance between nodes and potential locations. The objective function (5) is to maximize the coverage of demands by potential locations. Constraint (6) indicates that the chain retailer selected one site from several potential sites. Constraint (7) defines that total demands will be satisfied. Constraint (8) ensures that the potential locations cover all demand nodes. Constraint (9) states that the potential locations cover those demand nodes that are not tied with a competitor, while constraint (10) to those that are tied with a competitor. Constraint (11) ensures that a demand node is either tied or not tied. Constraints (12), (13), and (14) are integrality constraints for the problem variables. An illustrative example is exhibited in Appendix 2.

The example problem can also be transformed to a vertex P-center problem or a minimax problem (Owen and Daskin, 1998). For other models that basically consider distance and coverage factors, refer to the existing literature (e.g., Drezner, 1995b).

3.5 Location Selection Models Dealing with Future Conditions

So far we have introduced the deterministic models for location selection. Yet, the real-world problems are usually associated with uncertainty in the future. Some imminent changes may have already known today, such as target profits, cost reduction, population in an area, etc. For these known future risk problems, it is aimed at solving dynamic location problems (e.g., Current et al., 1997; Drezner, 1995a; Gunawardane, 1982).

Notwithstanding, it is clear that for many objectives, the future is unknown. In such cases, we need to deal with stochastic location problems. Stochastic problems have been extensively studied in the field (e.g., Daskin et al., 1997; Drezner and Drezner, 1998; Laporte et al., 1994; Shiode and Drezner, 2003; Weaver and Church, 1983).

This research presents a simple dynamic location model by adapting to the previous two-objective example. This model is developed based on Schilling's (1980; c.f. Owen and Daskin, 1998) mathematical formulation. For simplicity, we just repeat one of the two objectives of the previous problem. That is the objective to maximize the demand coverage. The current problem assumes that demand is time dependent. The dynamic problem is formulated below:

Objective:

Maximize $\sum_j \sum_t g_{jt}y_{jt} + \sum_j \sum_t g_{jt}z_{jt} / 2$ (15)

Subject to:

$\sum x_{it} = 1$ $\forall i,t$ (16)

$y_{jt} \leq \sum x_{it}$ $\forall i,j,t\ (j \in m_j)$, (17)

$z_{jt} \leq \sum x_{it}$ $\forall i,j,t\ (j \in n_j)$, (18)

$y_{jt} + z_{jt} \leq 1$ $\forall j,t$ (19)

$x_{it} \geq x_{i,t-1}$ $\forall i,t\ (t \neq 1)$ (20)

$x_{it} \in \{0,1\}$ $\forall i,t$ (21)

$y_{jt}, z_{jt} \in \{0,1\}$ $\forall j,t.$ (22)

Where:

i = the index of a potential location (potential department store);

j = the index of a demand node;

t = the index of the possible future period for location selection;

x_{it} = 1,0; 1 if a potential department store is intended to locate at i;

g_{jt} = demand at node j in period t;

y_{jt} = 1,0; 1 if demands at node j are fully captured in period t;

z_{jt} = 1,0; 1 if demands at node j are tied with a competitor in period t;

m_j = Demands at node j can patronize the location i;

n_j = A tie between a competitor and the location i with demands at node j.

The objective function (15) is to maximize the coverage of demands on condition that demands vary in different periods. Constraints (16), (17), (18), (19), (21), and (22) are the same as (6), (9), (10), (11), (12) and (14) respectively except that a time index is added to variables x, y, and z and coefficient g. Constraint (20) assumes that a location is selected for all possible future periods. Appendix 3 exhibits a simple illustrative example.

3.6 Conclusions

This chapter experiments some simple mathematical models for solving location selection problems related to real estate investment projects. Specifically, data envelopment analysis model is used for ratio problems. Deterministic and dynamic problems are also formulated using binary integer linear program models. Illustrative examples are provided. Other than the problem objectives suggested in this research, other objectives may be considered in individual location selection models. These objectives may be different in terms of nature or complexity. For example, models solving profit maximization problems have been addressed in the existing literature (e.g., Current et al., 1990; Plastria, 2001). Some refers to this as maximizing return on investment (ROI) location problems (e.g., Revelle and Laporte, 1996). Location-allocation problems involve more complicated formulation to simultaneously locate

facilities and determine flows between demands and facilities (Owen and Daskin, 1998).

From the experiment of the simple location selection models, it is identified that these simple models have difficulties in handling real estate location selection problems, due to the following reasons. First, factors related to real estate location selection problems can be both quantitative and qualitative, while the simple models can only deal with quantitative models. Second, because each real estate project has its own unique characteristics, constraints and requirements, the weightings of the factors may vary from project to project. Because of these difficulties in handing real estate location selection problems, direct use of the simple location selection models may not be applicable. This entails to explore other methodologies such as analytic hierarchy process (AHP) and the analytic network process (ANP), which are suitable for dealing with both quantitative and qualitative factors.

CHAPTER 4: THE ANALYTIC NETWORK PROCESS (ANP) APPROACH TO LOCATION SELECTION: A SHOPPING MALL ILLUSTRATION

This research presents the employment of the analytic network process (ANP) to select the best site for a shopping mall. ANP is a new and robust multi-criteria decision-making (MCDM) method because it can produce the most comprehensive analytic framework for solving societal, governmental, and corporate decision problems. Yet, there is a lack of published literature in the construction field demonstrating the method with illustrative examples. In this research, it is suggested that ANP is appropriate for shopping mall location selection. An example is therefore demonstrated. In order to explicate the difference between ANP and AHP, the findings obtained from the two methods are compared. Results of the comparison indicate that ANP is a powerful tool to solve the decision problem if interdependent relationships have substantial impacts in the decision model.

4.1 Introduction

Developing and running shopping malls is one of the major investment activities of commercial investors. In each and every investment assessment and decision, investors have to undergo a detailed feasibility study. Determining the best site for the shopping mall is a core constituent of the study (VAN, 1996). Other than using rudimentary methods, more sophisticated methods are suggested to provide more convincing results. It is because selecting a wrong location will damage the benefits of investment. This is consistent with Craig et al. (1984) who contended that a good location attracts shoppers and slight differences in location will affect market share and profit considerably.

Recently, multi-criteria decision-making (MCDM) methods are noted to be helpful in reaching important decisions that cannot be determined straightforwardly. The underlying principle of MCDM is that decisions should be made by use of multiple criteria. By applying the concept of MCDM, Professor Thomas Saaty (1980, 1996) created the analytic hierarchy process (AHP) and the analytic network process (ANP). Both methods are claimed to possess qualitative and quantitative components. On one hand they are used to identify decision criteria (qualitative component). This involves the creation of a structural model for the decision problem. On the other hand, they employ the procedure for assigning weights to the criteria (quantitative component).

However, AHP is restrictive to solve problems with a hierarchically structural model. ANP is a generic form of AHP as it can take interdependent relationships into consideration, resulting in the possibility to form a network-like structural model. ANP is therefore able to solve various decision problems because it can produce the most comprehensive analytic framework for making societal, governmental, and corporate decisions (Saaty, 2003).

Due to the complicated nature of shopping mall location selection, this research encourages the use of ANP in dealing with network decision models. The rest of this research is mainly organized to first present a background of ANP. A literature review of shopping mall location selection is then undertaken to identify key selection criteria. An illustrative example is provided to demonstrate how to put ANP into practice.

4.2 Background of ANP

AHP and ANP are multi-criteria decision-making tools, which are argued to possess qualitative (decision model development) and quantitative (decision model analysis) components. AHP models a hierarchical decision problem framework, which consists of multiple levels specifying unidirectional relationships. ANP models a network structure that relaxes the hierarchical and unidirectional assumptions in AHP to allow interdependent relationships in the decision making framework. Although the two decision tools possess the same qualitative and quantitative procedures to structure and analyze a decision problem, ANP needs further quantitative steps to solve a network decision problem. According to Cheng and Li (2004), ANP is composed of four qualitative (1to 4) and five quantitative (5 to 9) steps, which are described below:

i. *To state the decision problem* – The topmost level is to state the decision problem. This starts the decomposition of further levels down the structure until final level that is usually the scenarios or alternatives to be selected.
ii. *To make sure that the decision problem is to be solved by ANP* – As already stated, ANP is used to structure a decision problem into a network form. For solving strictly hierarchical model, AHP is sufficient.
iii. *To structure the unstructured decision problem* – The topmost decision problem level is abstract in nature. It must be decomposed into a set of manageable and

measurable levels until the level of criteria for assessing the scenarios or alternatives.

iv. *To determine who the raters are* – Those who are responsible for making the decision are the raters for completing a questionnaire.

v. *To design a questionnaire for eliciting data from raters* – It is suggested to use the pair-wise comparison, which can elicit more information to assign weights to the rated elements. It is common to use the 9-point priority scale to estimate the relative importance between paired elements (Saaty, 1980). The example presented in this research shows samples of the scale.

vi. *To calculate the eigenvector of each of the developed matrices* – Each decomposed level with respect to a higher level forms a matrix. It is necessary to calculate the eigenvector for the elements of this matrix. For the algorithm, refer to Saaty (1980) or Cheng and Li (2001).

vii. *To measure the consistency ratio (CR) of each of the matrices to find out the inconsistency of rating* – One of the best reasons to use pair-wise comparison and matrix is to measure the CR to ascertain that raters are consistent in rating. If the CR value cannot pass the acceptable level, it is certain that the raters rated arbitrarily or mistakenly. Re-rating is then needed. For the algorithm to calculate CR, refer to Saaty (1980) or Cheng and Li (2001, 2003).

viii. *To form the super matrix by the eigenvectors of the individual matrices (also known as sub matrices)* (Saaty, 1996) – The eigenvectors of each of the developed matrices should gather together to form a super matrix.

ix. *To compute the final limit matrix* – In order to compute the final limit matrix, the super matrix, which has been ensured of column stochastic, has to raise to high power until weights have been converged and remain stable (Sarkis, 1999).

4.3 Necessity of Shopping Mall Location Selection

The emergent modern lifestyles have shifted our shopping habits from patronizing small independent shops nearest to one's place of residence to large regional shopping malls. It is because large shopping malls provide a variety of goods (e.g., supermarkets, boutiques) and services (e.g., banks, cinemas) and is a place of modernization and cleanliness for attracting shoppers. As compared to small outlets, large malls are perceived to offer goods and services being of high quality, wide selection, and latest styles. This is consistent with what Finn and Louviere (1990) found that people have a negative perception on discount department stores in quality, selection, service, and fashions as opposite to major department stores. In consequence, the existence of large shopping malls is a symbol of high quality of life. As Shim and Eastlick (1998) found, people patronizing regional malls place stronger emphasis on self-actualization and social affiliation values. This is similar to what Burns and Warren (1995) referred to as shoppers' need for uniqueness.

4.3.1 Factors Affecting Shopping Mall Location Selection

Due to the growing interest of people patronizing shopping malls, investors are more willing to place their investments in shopping mall business. As Standard & Poor's (S&P, 2001) stated, investors in regional and super-regional malls would maintain their return on investment, which even increase in the future, despite the highly competitive and dynamic retail marketplace in the U.S. In Hong Kong, due to the growing northward shift of shopping from local retailers to those in the southern cities of mainland China (e.g., Guangzhou, Shenzhen), it is critical to think of new policies or ideas to prevent such an extreme imbalance of cross-border spending. One possible way is to build state-of-the-art shopping malls that provide multi-functional activities for attracting local shoppers to spend in the territory.

However, there is a fundamental question always asked by investors. Where should we build a shopping mall that is profitable? It is common that there are a number of potential locations, which have their strengths and weaknesses from an investment perspective. Selecting the best site is always difficult to deal with (Berry et al., 1988). Other than focusing on shoppers' behaviors for the purpose of retailer selection and mall governance internalization (Brown 1991; Roy, 1994; Severin et al., 2001; Wakefield and Baker, 1998), this research focuses on identifying the criteria for shopping mall location selection. By knowing the criteria and their relative importance, investors are able to determine which location is the best to invest.

The existing literature lacks detailed discussion on shopping mall location selection criteria. It is able to think of these criteria based on the six major components of shopping mall investment as depicted in Figure 4.1. The first three components are referred to as the major phases of a project life cycle (Kartam, 1996), while the last three components are related to the business management of the shopping mall (Jones and Simmons, 1990). The six components are elaborated more as follows:

- Investment feasibility study – Investors need to conduct a feasibility study (including a pre-feasibility study) for each investment plan they launch. This study enables them to determine if a project is valuable. Throughout the study, expectations for a project would be identified, such as the project type (i.e., a shopping mall), investment budget, expected return on investment, etc.

- Design of the shopping mall – Once the shopping mall project is worth doing, the investor (usually called the client or developer) will invite design and engineering tenders from design and engineering consultants unless it has in-house architectural designers.
- Construction of the shopping mall – Once the design has been confirmed, the investor will invite construction tenders from main contractors unless it also runs contractor business.
- Leasing and promotion – Once the shopping mall has been constructed, the investor is involved in leasing activities. It has to promote its shopping mall facilities to potential retailers (potential tenants). Usually, this is composed of two stages. First, brand retailing chains are invited to lease. They would be given the choice of best locations in the shopping mall to open their outlets. With their lease agreements, the investor can undergo media promotion attracting other retailers to lease the remaining areas. This would also help to draw the public's (i.e., shoppers) attention to the new shopping mall.
- Property management – When the shopping mall starts to operate, property management takes the key role in maintaining the mall's attractiveness. These activities include lease management, environmental monitoring, health and safety, cleanliness and tidiness, renovation, holiday's entertainment, and regular media promotion.

- Business and marketing – Property management is commonly the last component to many shopping mall investment plans. However, this would miss an important component that governs the future of the shopping mall, which is business and marketing. Due to the lack of business and marketing experts, property management office can only undertake simple regular media promotion to keep the public informed of mall activities, investors should employ such experts, who can revitalize old-fashioned shopping malls by refurbishing the mall style, reorganizing shops' ingredient, and launching new promotion campaigns. They can further establish strategies to locate and allocate shopping malls in strategic demand areas to capture the maximal market share of shopping mall business.

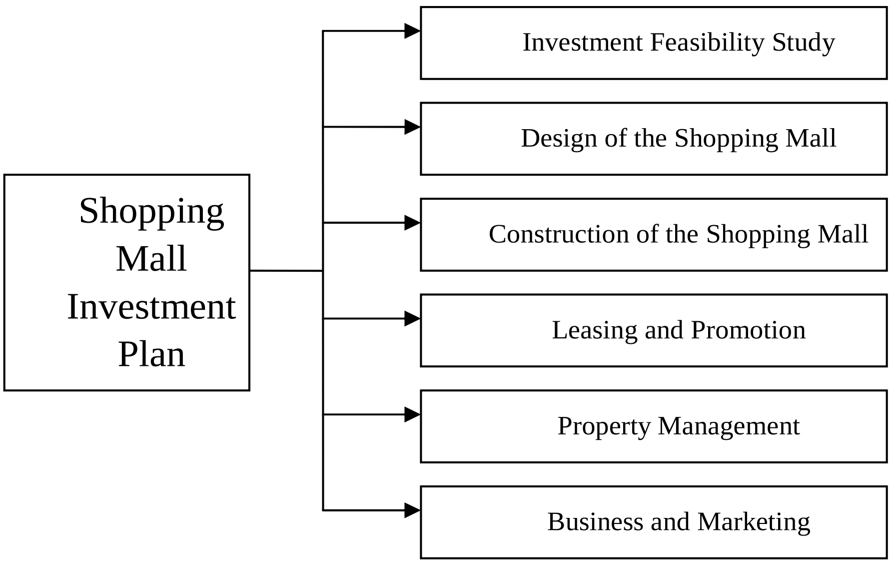


Figure 4.1 Shopping mall investment plan

4.3.2 Categories and Corresponding Criteria for Shopping Mall Location Selection

This study focuses on the first component of the ground work for a shopping mall investment plan. This is the feasibility study of a project. First, the investor conducts a pre-feasibility study to create the briefing stating what are expected to know in a feasibility study, which consists of seven basic questions described below (VAN, 1996):

- Where is the best location for carrying out the project?
- What is going to be constructed?
- What is the budget for the project?
- How much profit is expected to be generated from the project?
- How long will it take to run the project?
- How will the project be managed?
- How will the project be marketed?

Then, these questions are the objectives to be achieved in the feasibility study if the project should be undertaken. We can observe from the list of questions that selecting the best location is one of the basic objectives. This is consistent with Craig et al. (1984) who argued that the selection of the right location for a shopping mall project is of paramount importance. Among the four interdependent decisions for store location suggested by Berry et al. (1988), identification of feasible sites and selection of the one that can optimize the company's performance are two of them. Other key components involve (1) the expectation of project specification in terms of cost (budget), time (schedule), and profit (return on investment), (2) the determination of which type of project management to be used at the feasibility stage forms the guideline for the subsequent design and construction phases, and (3) project marketing linking to the later business management of the new shopping mall.

For identifying the selection criteria, the retail site appraisal and choice model of Berry et al. (1988) is useful. The model identifies five major parameters and four basic market research items for retail choices. Of these identified elements, some are able to form the criteria for selecting shopping mall location. For example, geographic limits, location type, competitors, and accessibility are suitable to assess the physical conditions of potential sites. In addition, it is expected that benefits of a good location mainly include a competitive advantage and return on investment (ROI). A competitive advantage helps the shopping mall sustain a long-term leading edge against competitors, while ROI is an indication for securing earnings from a short-term investment perspective.

In addition to the inclusion of physical location criteria, investor's capability is essential. It is expected that the weaker the management competence, the worse is the selected location. Additionally, the more the scarcity of financial resources of a company, the fewer the location options are for selection.

Besides considering the above points, the five categories of the 7E7 site selection criteria of the Boeing Company (2003) are also useful. For example, the easier the accessibility by shoppers, the more favorable the location is. Also, total cost of initial investment and environmental assessment should be considered in site evaluation. With the above viewpoints in mind, shopping mall location selection is anticipated to be associated with seven categories, which are transportation for shoppers, total cost of initial investment, environmental considerations, potential continuous development, transportation for suppliers, investor’s capability, and benefits of the investment.

Table4.1 exhibits the identified categories and corresponding criteria for shopping mall location selection. This is not an exhausted list of relevant criteria. Yet, they are expected to be generic critical factors appropriate to locate the best site for regional or super shopping mall investment in a city. For cross-area or even cross-boarder location-allocation decision problems, categories and their corresponding criteria that are specific to these requirements must be added in the decision model. Other specific categories and criteria can be integrated when they are deemed to be necessary by individual investors.

Table 4.1 Categories and corresponding criteria for shopping mall location selection

Category	Criterion
Transportation for shoppers	● Access by all local transportations ● Proximity to railways ● Proximity to major highways ● Proximity to piers
Total cost of initial investment	● Cost of land and buildings ● Construction cost ● Site preparation cost ● Other recurring and non-recurring costs (e.g., taxes, utilities, insurance, etc.)
Environmental considerations	● Noise pollution around the site ● Air pollution around the site ● Proximity to support services (e.g., fire, police, medical services, etc.)
Potential continuous development	● Continuous support of local residents ● Ability to expand or modify facilities ● Competitors already existed nearby ● Potential competitors within the area in the future
Transportation for suppliers	● Access by all local transportations ● Proximity to railways ● Proximity to major highways ● Proximity to piers
Investor's capability	● Business experience in shopping mall investment ● Financial resource ● Management competence
Benefits of the investment	● Return on investment ● Competitive advantage

4.4 An Illustrative Example

This hypothetical example is demonstrated to illustrate the use of ANP in shopping mall location selection. As previously noted, ANP is appropriate in solving problems that can be structured as a network-like decision models. For hierarchical decision models, decision-makers can rely on the AHP method.

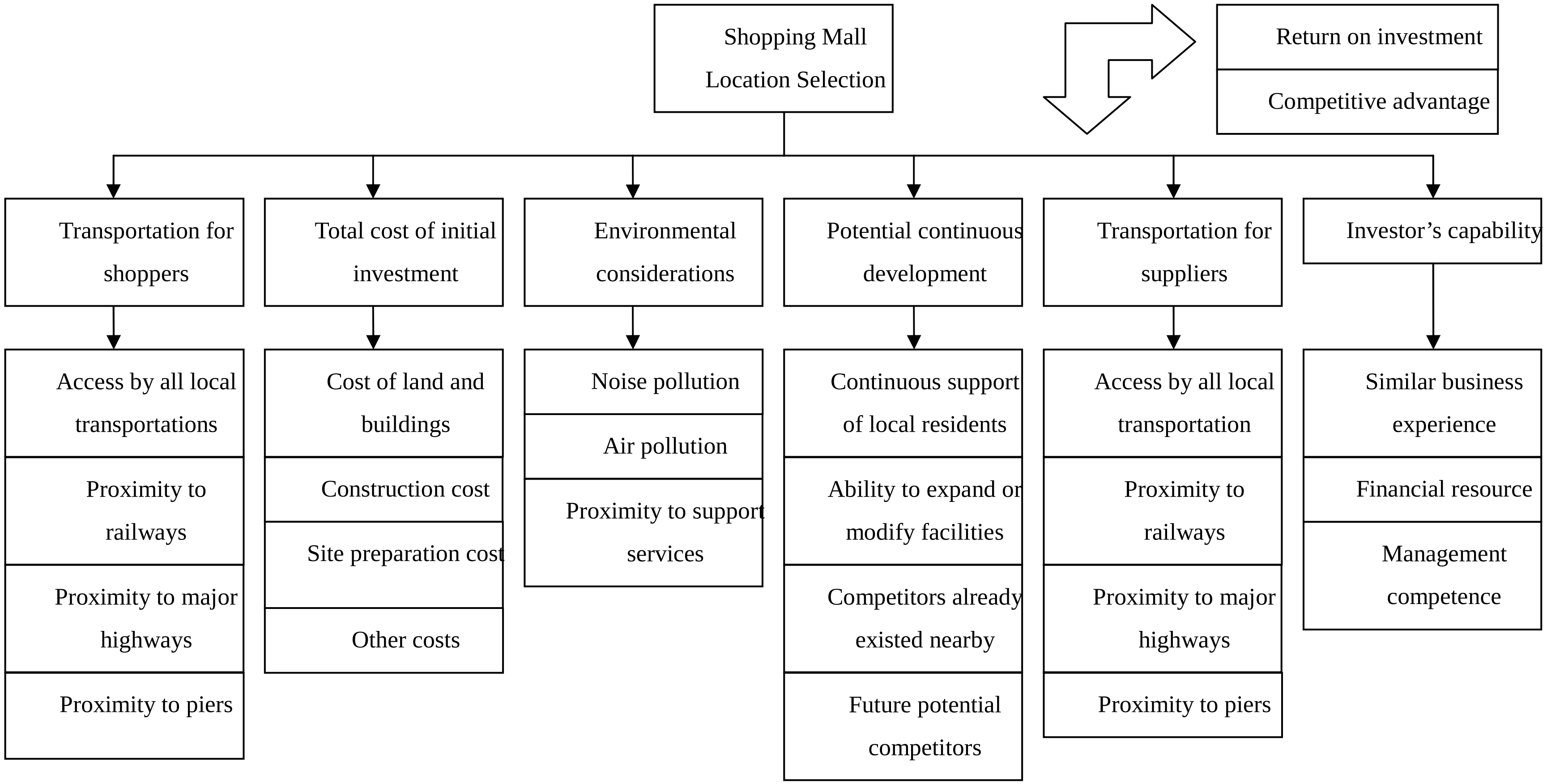
4.4.1 Development of the Decision Model

Prior to any data collection, the first thing to do is to develop a conceptual model for the decision problem. This is the most important part in the qualitative component of ANP as this conceptual model drives all subsequent works for solving the decision problem. As mentioned earlier, the first level of a decision model is the decision problem itself. This illustrative example is intended to select the best site for investing in the construction of a shopping mall. Therefore, the first level is to "select the best site". In order to achieve this goal, we should have several sites on hand for evaluation. Suppose that there are five potential locations appropriate for our selection model. Which one is the best must depend on measurable criteria. In simple evaluation models, there are only three levels – decision problem (the topmost level), criteria (the middle level), and selection options/alternatives (the bottom level). For more complicated models, other levels are added, such as categories of the criteria. Louviere and Meyer (1981), when selecting the decision criteria for supermarket choices, argued that only highly predictive criteria should be used. The current example adapts their views when developing the decision model.

Figure 4.1 illustrates the final decision model. Using the hierarchical information integration approach suggested by Louviere and Gaeth (1987), the decision model in this example consists of three levels. First, the topmost level is the decision problem – Shopping mall location selection. Then, the key categories and their

corresponding criteria (identified earlier in Table 4.1) form the second and third levels respectively. The final weighted criteria (the third level) are rated by raters and the score for each location option is calculated using the formula: $L_i = \sum_j W_j S_{ij}$ (where L_i is the location i, W_j is the weighted value on criterion j, and S_j is the score on criterion j, and where j = 1,…, 22). For example, the final score of location A, $P_A = W_1 S_{A1} + W_2 S_{A2} + \ldots + W_{22} S_{A22}$. In this example, elements in the second and third levels are weighted, while the final score for each location option is based on the composite view of a group of executives of a local corporate investor.

Figure 4.2 ANP decision model for shopping mall location selection


Shopping Mall Location Selection
Return on investment
Competitive advantage
Transportation for shoppers
Total cost of initial investment
Environmental considerations
Potential continuous development
Transportation for suppliers
Investor’s capability
Access by all local transportations
Proximity to railways
Proximity to major highways
Proximity to piers
Cost of land and buildings
Construction cost
Site preparation cost
Other costs
Noise pollution
Air pollution
Proximity to support services
Continuous support of local residents
Ability to expand or modify facilities
Competitors already existed nearby
Future potential competitors
Access by all local transportation
Proximity to railways
Proximity to major highways
Proximity to piers
Similar business experience
Financial resource
Management competence

Another component as shown in the decision model is that the above location selection categories are expected to be related to the return on investment (ROI) and competitive advantage. Studying their relationships is based on the inquiry that if the investor looks for more benefits, which category is more important in achieving this aim. In contrast, each category might have varied degree of importance in generating the two investment benefits. Therefore, ROI and competitive advantage, acting as external variables, form interdependent relationships with the six categories. This is the component that has to be solved by ANP.

4.4.2 Data Collection

For this strategic decision problem, the top management (or the project committee if any) should be responsible for ratings. It is common that one set of questionnaire should be completed based on the collective views from members of the top management. A sample of the questionnaire is shown in Figure 4.3. The questionnaire was created in accordance with the categories and associated criteria of the decision model. Each rated set in the questionnaire corresponds to each matrix of elements. Ratings were based on the Saaty's 9-point priority scale.

Please answer according to the following rating scale:

1 = the two items are **equally important**.
2 on the left (right) = the left (right) item is more important **to a small extent** than the right (left) item.
3 on the left (right) = the left (right) item is more important **to a moderate extent** than the right (left) item.
4 on the left (right) = an intermediate value between 3 and 5.
5 on the left (right) = the left (right) item is more important **to a large extent** than the right (left) item.
6 on the left (right) = an intermediate value between 5 and 7.
7 on the left (right) = the left (right) item is more important **to a very large extent** than the right (left) item.
8 on the left (right) = an intermediate value between 7 and 9.
9 on the left (right) = the left (right) item is more important **to an absolutely large extent** than the right (left) item.

Relative weights of the criteria with respect to environmental considerations
(Circle the number that mostly represents your viewpoint)

Column 1																		Column 2
Noise pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Air pollution
Noise pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Proximity to support services
Air pollution	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Proximity to support services

Figure 4.3 A Sample of the ANP/AHP Questionnaire

4.4.3 Eigenvectors of Matrices

Data of the completed questionnaire were entered into the MS Excel program, where formulas were constructed specifically for calculating relative weights of the elements of the matrices and the consistency ratio (CR) that located inconsistent rating. Alternatively, commercial software packages are available for computing relative weights and consistency ratios (e.g. Expert Choice for Windows, 1996). Saaty (1994) set three acceptable levels for CR values: (1) 0.05 for 3-by-3 matrix, (2) 0.08 for 4-by-4 matrix, and (3) 0.1 for all other matrices. If there is any part (i.e., a matrix) with an unacceptable CR value, re-rating the questionnaire on that part is needed. In order to improve the consistency in ratings, raters can be explained about the concept of pair-wise comparison.

Figures 4.4 and 4.5 show the relative weights (and CR values) for the category matrix and the six criteria matrices respectively. In Figure 4.4, the six categories (level 2 of the decision model) were rated pair by pair with respect to the decision problem (level 1 of the decision model). For example, investor's capability was three times more important than environmental considerations. In Figure 4.5, the criteria (level 3 of the decision model) were rated pair by pair with respect to their respective category (level 2 of the decision model). The CR values of all matrices are accepted. The last column of each matrix indicates the eigenvector of the rated items.

Matrix 1: Categories with respect to the decision problem

	TS	TC	EC	CD	TP	IC	EV
TS	1	1/2	2	2	1	1/2	0.149
TC	2	1	3	3	2	1	0.270
EC	1/2	1/3	1	1	1/2	1/3	0.082
CD	1/2	1/3	1	1	1/2	1/3	0.082
TP	1	1/2	2	2	1	1/2	0.149
IC	2	1	3	3	2	1	0.270
						CR =	0.003

Figure 4.4 Comparison of the Six Categories with Respect to the Decision Problem

Note: TS = transportation for shoppers, TC = total costs of initial investment, EC = environmental considerations, CD = potential continuous development, TP = transportation for suppliers, IC = investor's capability, EV = eigen value, CR = consistency ratio

Matrix 2: Criteria with respect to TS

	AC	PR	PH	PP	EV
AC	1	2	4	4	.500
PR	1/2	1	2	2	.250
PH	1/4	1/2	1	1	.125
PP	1/4	1/2	1	1	.125
				CR =	0

Matrix 3: Criteria with respect to TC

	CL	CC	SC	OC	EV
CL	1	1	3	5	.394
CC	1	1	3	5	.394
SC	1/3	1/3	1	2	.138
OC	1/5	1/5	1/2	1	.075
				CR =	.002

Matrix 4: Criteria with respect to EC

	NP	AP	PS	EV
NP	1	1	2	.400
AP	1	1	2	.400
PS	1/2	1/2	1	.200
			CR =	0

Matrix 5: Criteria with respect to CD

	CS	AE	CE	PC	EV
CS	1	1	1/3	1/3	.125
AE	1	1	1/3	1/3	.125
CE	3	3	1	1	.375
PC	3	3	1	1	.375
				CR =	0

Matrix 6: Criteria with respect to TP

	AC	PR	PH	PP	EV
AC	1	1	1	2	.286
PR	1	1	1	2	.286
PH	1	1	1	2	.286
PP	1/2	1/2	1/2	1	.143
				CR =	0

Matrix 7: Criteria with respect to IC

	BE	FR	MC	EV
BE	1	1/5	1/3	.110
FR	5	1	2	.581
MC	3	1/2	1	.309
			CR =	.003

Figure 4.5 Comparison of the Criteria With Respect to Each of the Six Categories

Note: AC = access by all local transportations, PR = proximity to railways, PH = proximity to major highways, PP = proximity to piers, CL = cost of land and buildings, CC = construction cost, SC = site preparation cost, OC = other costs, NP = Noise pollution, AP = air pollution, PS = proximity to support services, CS = continuous support of local residents, AE = ability to expand or modify facilities, CE = competitors already existed nearby, PC = future potential competitors, BE = similar business experience, FR = financial resource, MC = management competence

In Figure 4.6, the six categories were rated pair by pair with respect to ROI and competitive advantage, while in Figure 4.7. The latter two items were also rated in pair with respect to the six categories. The eigenvectors of the resulting eight matrices formed the super matrix.

Matrix 8: Categories with respect to return on investment

	TS	TC	EC	CD	TP	IC	EV
TS	1	1/2	1	2	1	1/2	0.124
TC	2	1	3	5	4	1	0.303
EC	1	1/3	1	3	2	1/3	0.130
CD	1/2	1/5	1/3	1	1	1/5	0.060
TP	1	1/4	1/2	1	1	1/4	0.080
IC	2	1	3	5	4	1	0.303
						CR =	0.017

Matrix 9: Categories with respect to competitive advantage

	TS	TC	EC	CD	TP	IC	EV
TS	1	2	2	1	3	1	0.218
TC	1/2	1	1	1/3	1	1/4	0.086
EC	1/2	1	1	1/2	1	1/3	0.096
CD	1	3	2	1	4	1	0.243
TP	1/3	1	1	1/4	1	1/5	0.074
IC	1	4	3	1	5	1	0.284
						CR =	0.013

Figure 4.6 Comparison of the Six Categories With Respect to the Investment Benefits

Matrix 10: Benefits with respect to TS

	ROI	CA	EV
ROI	1	2	0.67
CA	1/2	1	0.33
		CR =	N.A.

Matrix 11: Benefits with respect to TC

	ROI	CA	EV
ROI	1	2	0.67
CA	1/2	1	0.33
		CR =	N.A.

Matrix 12: Benefits with respect to EC

	ROI	CA	EV
ROI	1	1	0.50
CA	1	1	0.50
		CR =	N.A.

Matrix 13: Benefits with respect to CD

	ROI	CA	EV
ROI	1	1/2	0.33
CA	2	1	0.67
		CR =	N.A.

Matrix 14: Benefits with respect to TP

	ROI	CA	EV
ROI	1	2	0.67
CA	1/2	1	0.33
		CR =	N.A.

Matrix 15: Benefits with respect to IC

	ROI	CA	EV
ROI	1	1	0.50
CA	1	1	0.50
		CR =	N.A.

Figure 4.7 Comparison of the Investment Benefits with Respect to Each Category

Note: ROI = return on investment, CA = competitive advantage, N.A. = not applicable

4.4.4 The Super-matrix

Table 4.2 illustrates the super-matrix that consists of the eigenvectors associated with the six categories. More specifically, the super-matrix includes the eigenvector of the matrix that compared the six categories with respect to the decision problem. Other included eigenvectors are the matrices formed due to the interdependent influences between the six categories and the two major benefits of the investment.

Table 4.2 the Super-matrix

	SL	TS	TC	EC	CD	TP	IC	ROI	CA
SL	0	0	0	0	0	0	0	0	0
TS	0.149	0	0	0	0	0	0	0.124	0.218
TC	0.270	0	0	0	0	0	0	0.303	0.086
EC	0.082	0	0	0	0	0	0	0.130	0.096
CD	0.082	0	0	0	0	0	0	0.060	0.243
TP	0.149	0	0	0	0	0	0	0.080	0.074
IC	0.270	0	0	0	0	0	0	0.303	0.284
ROI	0	0.67	0.67	0.50	0.33	0.67	0.50	0	0
CA	0	0.33	0.33	0.50	0.67	0.33	0.50	0	0

Note: SL = shopping mall location selection

After the super-matrix was assured of column stochastic, the super-matrix was raised to sufficient large power until convergence occurred (Saaty, 1996). Given the irreducible super-matrix, it was raised to the power 2k+1 and converges if $k \rightarrow \infty$ (Saaty, 1996; Meade and Sarkis, 1998). In the current study, convergence is stable at W^{10} with cyclical ratios. Table 4.3 exhibits the average limiting super-matrix, relative importance of criteria, and final weights of criteria.

Table 4.3 The Final Weights of Criteria

	The normalized value of a category from the average limiting super-matrix	The relative weight of criterion	The final weights of criterion
TS	0.166		
AC		0.500	0.083
PR		0.250	0.042
PH		0.125	0.021
PP		0.125	0.021
TC	0.206		
CL		0.394	0.081
CC		0.394	0.081
SC		0.138	0.028
OC		0.075	0.015
EC	0.115		
NP		0.400	0.046
AP		0.400	0.046
PS		0.200	0.023
CD	0.142		
CS		0.125	0.018
AE		0.125	0.018
CE		0.375	0.053
PC		0.375	0.053
TP	0.077		
AC		0.286	0.022
PR		0.286	0.022
PH		0.286	0.022
PP		0.143	0.011
IC	0.294		
BE		0.110	0.032
FR		0.581	0.171
MC		0.309	0.091

4.5 Discussion

Table4.4 indicates the findings of ANP and AHP. In ANP, interdependent relationships between the investment benefits and the categories were taken into consideration. The findings support that site 2 should be chosen as it has a higher weighted score (7.127) than site 1 (7.118). In AHP, interdependent relationships were ignored. In this case, the findings support the selection of site 1 as it has a higher weighted score (6.776) than site 2 (6.729).

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Table 4.4 Comparison of the Findings of ANP and AHP

	ANP			AHP		
	Criterion's weight	Site 1	Site 2	Criterion's weight	Site 1	Site 2
AC	0.083	7	6	0.075	7	6
PR	0.042	8	6	0.037	8	6
PH	0.021	7	7	0.019	7	7
PP	0.021	4	8	0.019	4	8
CL	0.081	8	8	0.106	8	8
CC	0.081	8	7	0.106	8	7
SC	0.028	6	7	0.037	6	7
OC	0.015	6	6	0.020	6	6
NP	0.046	7	8	0.033	7	8
AP	0.046	5	8	0.033	5	8
PS	0.023	7	5	0.016	7	5
CS	0.018	4	5	0.010	4	5
AE	0.018	8	6	0.010	8	6
CE	0.053	9	6	0.031	9	6
PC	0.053	7	8	0.031	7	8
AC	0.018	7	7	0.043	7	7
PR	0.018	6	8	0.043	6	8
PH	0.053	8	7	0.043	8	7
PP	0.053	5	9	0.021	5	9
BE	0.032	7	5	0.030	7	5
FR	0.171	5	5	0.157	5	5
MC	0.091	7	7	0.083	7	7
	Weighted Mean =	7.118	7.127	Weighted Mean =	6.776	6.729

Note:

(1) Criteria' weights were normalized. The criteria were rated based on a ten-point scale from 1 (= lowest important) to 10 (= the most important).

(2) Keep three decimal places.

This example suggests that interdependencies are able to affect the decision to be made for an investment plan. For network-like decision models (i.e., decision problems that can be structured as a network model), ANP is an effective tool to provide an accurate solution for the company.

4.6 Conclusions

This research presents the use of ANP in shopping mall location selection. ANP is argued to be able to solve all kinds of decision problems that we might encounter. It focuses on how to identify decision criteria (by structuring a decision model) and how to weight the criteria (by use of pair-wise comparison). An example is demonstrated to put it into practice. The findings of ANP and AHP are also compared, which support that the former is a powerful tool if the decision model is substantially affected by interdependent relationships.

CHAPTER 5: A GIS APPROACH TO SHOPPING MALL LOCATION SELECTION

This research presents the use of geographic information systems (GIS) for shopping mall location selection, which is one of the core business activities of developers for long-term capital investment. A GIS-based system uses electronic mapping technology in producing interactive multi-layer maps so that queries are set to find optimal solutions for problems. It combines spatial and non-spatial data to construct visualized information that can be easily analyzed by decision makers and that cannot be achieved in table or list forms. In the current research, a project is demonstrated to create features associated with household incomes, demand points, etc. Queries are then created for finding solutions for four location problems: (1) minimum distance, (2) maximum demands coverage, (3) maximum incomes coverage, and (4) optimal center.

5.1 Introduction

Construction projects involve huge amount of long-term capital investment and the annual accumulated spending always represents a certain percentage of gross domestic product (GDP). On that account, each part of a project life cycle must be careful to determine before undertaking. Owing to the complicated nature of a construction project, decision-making becomes a significant but difficult process. Among those numerous decisions having to make for a project, a core decision that has to be made by developers is always undervalued, which is location selection.

Location selection is usual for both public and private projects. For example, the Fire Department needs to select a site for locating a fire station, while a bank would like to attract more customers by locating their branches strategically. Nevertheless, many of these location selections are done by simple analysis in terms of rudimentary calculation, past experience, or even predilection.

Other than simple methods, more sophisticated ones have also been proposed, which make use of statistical and mathematical tools (e.g., Molenaar and Songer, 1998; Owen and Daskin, 1998). Yet, these methods are not user-friendly in certain ways, especially when presenting the progress or results to the management. Taking the advantage of information technology, geographic information systems (GIS) enable the handling of both spatial and non-spatial data, leading to its specific roles in data management and integration, data query and analysis, and data visualization (Li et al., 2003). A GIS combines spatial and non-spatial data to construct thematic maps depicting a variety of demographic information relating to population, housing, and economic activities.

Its application on the technical area in the construction industry is evident (e.g., O'Rourke and Pease, 1997), while its usefulness to the non-technical area is being explored. In view of the potentiality of the GIS, this research presents a research that explores its utility by demonstrating an illustrative project that uses a GIS for shopping

mall location selection. The following sections are organized to present: (1) a background of shopping mall location selection, (2) a description of the GIS technology, (3) an application of a GIS for super mall location selection, and (4) solutions for four different location selection problems.

5.2 Research Limitation in Shopping Mall Location Selection

Due to the emergence of modern lifestyles, retail shopping has shifted from shopping at small independent shops to large retail outlets and from patronizing at shops nearest to one's place of residence to regional shopping malls. Understanding the behavior of shopping may guarantee a satisfied profit margin for retail investors. For more than half a century, research on shopping behavior has been regarded as the study of consumer behavior and patronage behavior.

According to Brockman et al. (2001), most of the research examining the relationship between consumer behavior and shopping mall has spent on studying motivational factors of consumers for shopping in retail shopping centers. Earlier research can be found from Dommermuth and Cundiff (1967) who studied consumer interests and Cox and Cooke (1970) who studied driving time, through to Grossbart et al. (1975) who examined consumer perceptions, attitudes, and behaviors relating to the area surrounding the shopping center and Bellenger et al. (1977) who identified the two distinct shopper types being economic versus recreational shoppers.

Later research extends to cover wider aspects of consumer behavior. Feinberg et al. (1989) found that malls serve as a place for stimulating social behavior. Brown (1991) further studied shopper circulation in desired shopping centers, finding that movements of most shoppers restrict to a relatively small part of a mall. Roy (1994), on the other hand, investigated characteristics of shoppers on mall shopping frequency. Bloch et al. (1994), regarding a mall as a consumer habitat, found that considerable heterogeneity exists among mall consumers. The work of Burns and Warren (1995) attributed shoppers' behavior to shop in regional shopping malls to individual's need for uniqueness. Finn and Louviere (1990) examined the relationship of mall retail outlets and mall image by comparing discount department stores and major department stores. Results indicated that discount department stores, as opposite to major department stores, had a consistently negative impact on such center perceptions as high quality, wide selection, good service, and latest fashions.

Research focusing on patronage behavior can be traced back to Huff (1964) who developed a disaggregate-probabilistic patronage model based upon earlier gravity models (e.g., Reilly, 1929; Converse, 1949; c.f. Gautschi, 1981). During the past four decades, other patronage models have also been established (e.g., Gautschi, 1981, Timmermans, 1982; Weisbrod et al., 1984; Severin et al., 2001). Many of which have based their models on the central place theory, which links to the variables of selling space and travel time. Other patronage research underwent empirical tests. For example, Wakefield and Baker (1998), examining the effects of tenant variety, mall environment,

and consumer shopping involvement on shoppers' excitement and desire to stay at a mall, found that tenant variety is mostly related to shoppers' excitement, while mall environment is mostly related to shoppers' desire to stay.

For the benefit of shopping mall research, combining the two study areas (i.e., consumer behavior and patronage behavior) moves to a more valid application of the existing knowledge. This is consistent with Finn and Louviere (1990) who envisaged the creation of consideration sets in identifying shopper segments, which help locate the dissemination of shoppers within a geographical region. On that account, a GIS is one of the most appropriate methods for shopping mall location selection.

5.3 Application of a GIS for Shopping Mall Location Selection

5.3.1 Background of the Project

The current research presents an application of a GIS for shopping mall location selection. This study is initiated due to the growing evidence of cross-border shopping trend from local retailers to those in China. Such northward moving expenditures slow down the recovery of the local economy. In order to convince people to spend their money in the territory, it is essential to establish new developments, such as building attractive resort facilities on outlying islands, promoting social and cultural activities, and other potential leisure initiatives (BEA, 2001). One of these initiatives is to build state-of-the-art shopping malls, which are attractive and multi-functional, in high spending demand areas. Such greatly attractive shopping malls are always known as regional or super malls.

Most of the local shopping malls are small and medium-sized, while world-class super malls are mainly located in premium areas. Some of these super malls may no longer be attractive due to their old-fashioned design and image. The growth in population and the enormous shift of people from old to newly developed districts also create new spending demand areas. Therefore, it was high time to think of new sites for locating attractive shopping malls, which must be multi-functional, large in size, and exclusive.

The advantage of super malls has been evident in other areas, such as the United States. Standard & Poor's (S&P, 2001) announced that while the highly competitive and dynamic retail marketplace continued to consolidate, regional malls were able to survive and even prosper. The company further recognized that despite the temporary low in mall sales and the proximity of sizeable number of independent stores, regional and super-regional malls were weathering the storm by maintaining stable commercial mortgage transactions. This is consistent with Burns and Warren (1995), who examined the reasons why it is common for people to shop at a regional shopping mall other than the one nearest to their places of residence, found that the situation is due to shoppers' need for uniqueness.

5.3.2 Major Steps for a GIS

A GIS approach to mall location selection consists of several steps in making use of maps and primary data for producing digital maps at different layers (an interactive distribution network for making decisions). First, one has to think of what the GIS project is all about. The current project is to select the best location(s) for constructing super shopping malls. Therefore, both explicit geographic references and implicit references are needed. Specifically, a digital map is required to outline the potential area for locating the mall. In this project, the whole city of Hong Kong is under consideration. A GIS-based system is able to produce digital maps, which form the basis for locating streets, roads, and railways in different map layers.

The next step is to determine what specific geographic features are needed. This involves the determination of the level of detail required from the data (e.g., spatial data such as streets and buildings, tabular data such as household demographic profiles). It needs to choose a scale to illustrate local map details (in this project, the centimeter scale was 1:487,909) and it is common to use coastlines, connected routes (for nodes) by lines, and colors to represent different features and attributes.

Primary data regarding shoppers' behavior and demographic profiles obtained by means of surveys are entered into the system to act as the features for other layers. With respect to data model, the current project uses the vector data model to construct the route map and locate customers and malls and summarizes demographic profile by district areas.

Then, we have to determine what attributes of the features are needed. For example, we can set for the connected routes with such attributes as name, route number, altitude, and traffic volume. In the current project, distance measured in kilometer was recorded for each route. We also collected data for establishing layers for spending demands and household incomes. In addition, a layer is created for locating potential sites. All the data can be integrated and manipulated to address site location issues. Figure5.1 exhibits how a GIS acts as a data integrator (Li et al., 2003). This involves executing the sequential access storage in the multi-layer GIS architecture.

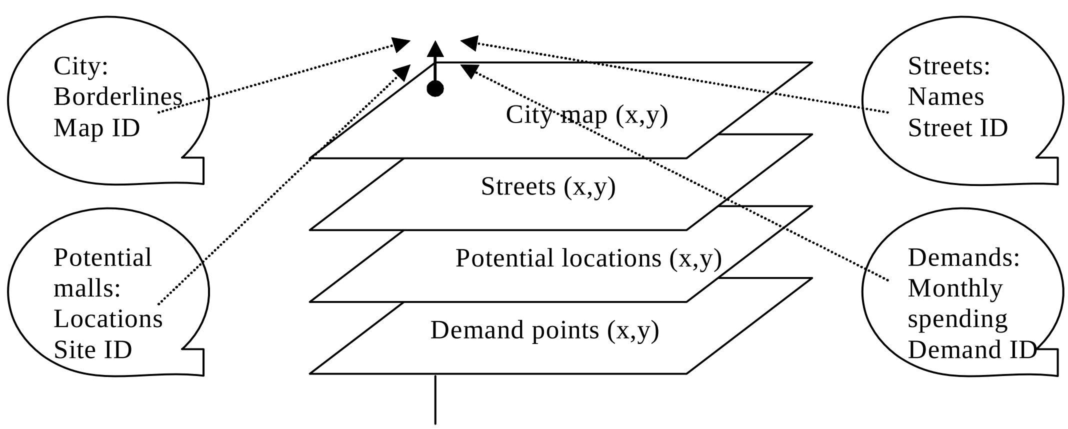

Figure 5.1 Examples of data integration in a GIS

Once the data have been stored in relevant locations, they would be linked up together in the system through the geographical database in order to provide necessary information for users to make decisions. In order to avoid confusion, the map of each layer should be distinctive and can be distinguished from each other. Usually, this can be achieved by symbolization with different colors so that features are grouped in accordance with their attribute values. For example, a layer uses different colors to represent district areas. Streets, roads, and railways use different thickness of lines and/or different line colors. Small locations, such as facility sites, are presented by use of points and labels. Table 5.1 lists samples of details of map layers.

Table 5.1 A List of Sample Layers and Sub-Layers in a GIS

Layer and sub-layer	Description of the features	Symbolization
City map	Draw an outline of the city	Coastlines covering the whole city
District areas	Divide the city into ten district areas	Ten different colors representing the ten districts
Roads	Draw roads on the city map	Lines with brown color
Streets	Draw streets on the city map	Lines with red color
Railways	Draw railways on the city map	Lines with dark green color
Existing shopping malls	Locate the existing shopping malls on the city map	Points with labels in alphabet and number as E1, E2, etc.
Potential locations	Locate the potential sites on the city map	Points with labels in alphabet and number as S1, S2, etc.
Household incomes in each district	Add up the average monthly household incomes generated in each district	Points at the centers of districts with labels in alphabet and number as H1, H2, etc.
Demand size in each district	Add up the average monthly demands (spending) in each district	Points at the centers of districts with labels in alphabet and number as A1, A2, etc.
Household incomes in each estate	Add up the average monthly household incomes generated in each estate point	Points with labels in alphabet and number as M1, M2, etc.
Demand size in each density point (demand point)	Add up the average monthly demands (spending) in each density point	Points with labels in alphabet and number as D1, D2, etc.

5.3.3 Maps Created by GIS Software

The current project can be developed by most of the existing GIS software packages. In general, the GIS software builds in the functions and tools for storing, analyzing, and displaying necessary information. There are four key parts of the GIS software (GIS, 2003):

(1). Tools that help enter and manipulate geographic information (e.g., district borders, street names, etc.),

(2). A database management system (DBMS),

(3). Tools for creating intelligent digital maps for analysis, queries, and printing, and

(4).An easy-to-use graphical user interface (GUI).

As stated earlier, digital maps of different features are stored in the GIS-based system and are able to combine to form useful information. Figure5.2 exhibits how two map layers can be combined to form an informative map.

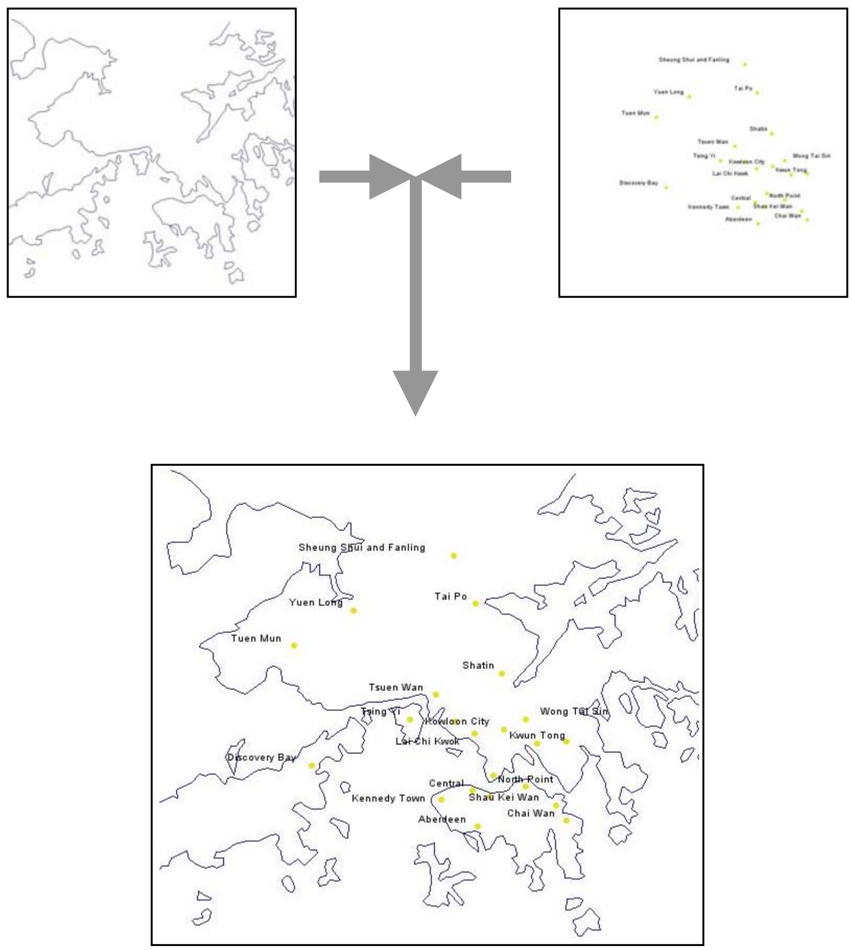

Figure 5.2 Combination of the map layers of coastlines and major demand points

Five basic layers were developed for the current project. The first was a coastline map of Hong Kong. Then, a layer in the system represented the average monthly demand information covered in areas. For simplicity, a point density was used instead to represent an area demands. In reality, a point density could be a residential, commercial, or industrial area. Since data about residential areas could be provided in governmental publications, a point density was then referred to as a residential district.

The third layer represented the household incomes information. This was the average monthly household income for a district. Districts that were close to each other were grouped together. For example, Wanchai consisted of the areas of Wanchai, Causeway Bay, and Happy Valley. Admiralty was a part of Central, while Kowloon Tong was a part of Kowloon City.

The fourth layer covered the potential sites of super mall. Altogether there were eight locations. The fifth layer indicated six existing super malls. All data were provided by the Census and Statistics Department (CSD, 2001). Figure5.3 illustrates locations of potential sites, major demand points, and existing malls. By setting different queries, the attributes in the layers can combine to form the necessary information for solving decision problems. The next section would deal with four common problems in location selection, which can now be solved by a GIS-based system.

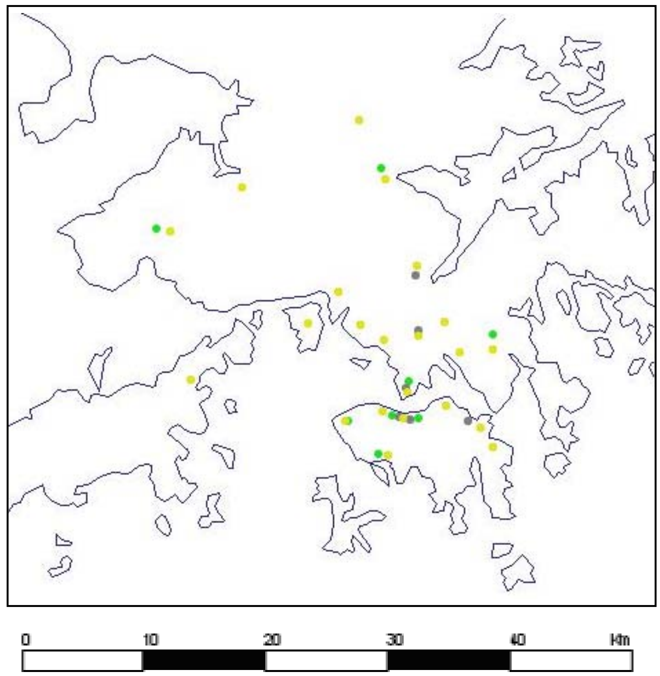

Figure 5.3 Locations of Potential Sites, Major Demand Points, and Existing Malls

5.3.4 Queries and Solutions for Four Location Problems

After having set up a GIS, it is able to create the queries for finding solutions addressing location problems. This research presents possible queries and solutions regarding four common location problems: (1) minimum distance, (2) maximum demand coverage, (3) maximum average monthly incomes coverage, and (4) optimal center.

Minimum Distance Problem

Prior to addressing any distance problems, it is crucial to identify the target demand points and to determine how to calculate a distance. In Hong Kong, there is a transportation network such that all major areas can be reached by less than two hours. It is therefore assumed that a super mall is attractive to and can be accessible by all local major demand areas. In other words, it is expected to be located in the heart of Hong Kong. The problem is set to measure the level of convenience. For calculating a distance, Li et al. (2003) suggested that the most popular approach is to calculate the shortest path between two points in a network by use of Dijkstra's (1959) algorithm. A formula is set to calculate the mean of distances from all major demand density points to each potential location. There were twenty-two major demand areas identified in Hong Kong and eight potential locations proposed in this project. Therefore, the formula is: $D_i = [\sum_j(X_{ij})]/22$ where D_i = average distance for location i, X_{ij} = distance between potential location i and demand density point j, i = 1…8, and j = 1…22. The one with the minimal average distance is the best location.

In a GIS, X_{ij} can be easily obtained using the measure function, which measures the distance between two points automatically once a line or multiple lines connecting them has been created. By ordering a proper command, an array of distances can be summed up and taken average to obtain D_i. Table 5.2 exhibits the query results, indicating that Tsimshatsui is the best location. In other words, Tsimshatsui is the geographical center of Hong Kong with respect to all local major demand density areas.

Table 5.2 Average Distance from Major Demand Points

Potential location	Total distance (kilometer) (round up to an integer)	Average distance (kilometer) (round up to two decimal places)
Aberdeen	258	11.73
Central	210	9.54
Causeway Bay	219	9.96
Kennedy Town	232	10.54
Tsimshatsui	192	8.72
Tseung Kwan O	256	11.64
Tai Po	340	15.47
Tuen Mun	455	20.70

Maximum Demands Coverage Problem

In order to set a query for maximum demands coverage for the best location, it is required to set a formula to sum up the average monthly demand (density points) covered for a given distance measured from a potential location. Given a presumed level of convenience, far distant demands have to be excluded. In a GIS, this can be easily achieved by drawing a circular zone around each potential location using the buffer function. This buffer zone was the "window" used to view how many demand points covered with a radius. Such a buffer zone is various in different areas in Hong Kong due to different traveling times of different areas. Thus, it is assumed that a buffer zone is greater in areas connected by highways (e.g., Tuen Mun and Yuen Long) and railroads (e.g., areas connected by Mass Transit Railway and Kowloon-Canton Railway). Buffer zones of other crowded areas that are connected by roads and streets (e.g., Kennedy Town and Aberdeen) are smaller. The radius of the former is set to 10 km, while that of the latter is 5 km. Column 2 of table 5.3 exhibits the covering demand areas for each potential location.

Another mathematical expression is set to assume that if a potential location is in close proximity to another existing super shopping mall (i.e., within the same district), the potential demand for this location will be half. The potential demand will be one-third if two malls have existed, and so forth. Column 3 of table 5.3 exhibits the existing super mall(s) for each potential location. The query results (Column 4 of table 5.3) indicate that Tuen Mun is the best location as it has the maximum demands coverage.

Table 5.3 Query Results Relating to Demands and Household Incomes

Potential location	Coverage demand area	Existing super mall	Coverage demand (mean)	Coverage household income (mean)
Aberdeen	Aberdeen, Kennedy Town, Central, Wanchai.	None	179817	28400
Central	Central, Kennedy Town, Aberdeen, Wanchai, Tsimshatsui.	Admiralty (1)	200258	25661
Causeway Bay	Wanchai, Central, Aberdeen, Tsimshatsui, North Point.	Causeway Bay (1)	289890	27929
Kennedy Town	Kennedy Town, Central, Aberdeen.	None	184041	29201
Tsimshatsui	Tsimshatsui, Kowloon City, Shamshuipo, Kwun Tong, Central, Wanchai, North Point.	Tsimshatsui (3)	87733	23600
Tseung Kwan O	Tseung Kwan O, Wong Tai Sin, Kowloon City, Kwun Tong	None	429024	18163
Tai Po	Tai Po, Northern District, Shatin	None	412723	18877
Tuen Mun	Tuen Mun, Yuen Long	None	468951	16500

Note: Number in parenthesis denotes the number of existing super mall(s) close to the potential location.

Note: The statistical data are collected from the Department of Statistics from the SAR Hong Kong.

Maximum Incomes Coverage Problem

Maximum incomes coverage is purposely defined as maximizing the average monthly incomes covered for a given distance measured from the potential location. It is similar to maximum demands coverage with the difference that the former focuses on density points in terms of household incomes rather than spending demands. The last column of table 5.3 exhibits the query results, which indicate that Kennedy Town is the best site.

Optimal Center Problem

Pertaining to mathematical models, center problems are typical minimax problems (Owen and Daskin, 1998). In general, it takes both maximum demands and minimum distance problems into consideration. A formula is set to calculate the ratio of demands from a node over the distance between the nodes of a covered demand point and a potential location. The sum of ratio values of all demand areas are averaged with respect to each potential site to obtain an approximate location value (i.e., average ratio value). Noteworthy, the calculation is subject to the abovementioned mathematical requirement due to existing shopping mall(s). For example, for the potential location “Central”, the coverage demand areas were Central, Kennedy Town, Aberdeen, Wanchai, and Tsimshashui. There was a super mall in Admiralty, which, as earlier mentioned, was included in the area of Central. As a result, the mathematical expression was: [(93848/1

+ 168036/3.835 + 290240/3.087 + 167146/1 + 282020/1.998) / 5] / 2 = 53998. It is noted that location distances less than 1 were rounded up to 1. Table 5.4 exhibits the query results. Tuen Mun yields the largest value, and thus it is the best location.

Table 5.4 Optimal Center Solution

Potential location	Coverage demand area	Average ratio value
Aberdeen	Aberdeen, Kennedy Town, Central, Wanchai.	102646
Central	Central, Kennedy Town, Aberdeen, Wanchai, Tsimshatsui.	53998*
Causeway Bay	Wanchai, Central, Aberdeen, Tsimshatsui, North Point.	60817*
Kennedy Town	Kennedy Town, Central, Aberdeen.	91605
Tsimshatsui	Tsimshatsui, Kowloon City, Shamshuipo, Kwun Tong, Central, Wanchai, North Point.	30708*
Tseung Kwan O	Tseung Kwan O, Wong Tai Sin, Kowloon City, Kwun Tong	172283
Tai Po	Tai Po, Northern District, Shatin	153856
Tuen Mun	Tuen Mun, Yuen Long	274595

Note: * denotes that the average ratio value was also divided by “one plus the number of existing super mall(s)”.

5.4 Conclusions

The current research presents the application of a GIS in shopping mall location selection. This application is inclined more towards business rather than technical problem area. Specifically, it combines spatial (geographical) and non-spatial (market-oriented) data to construct visualized information that can be easily understood and analyzed by decision makers and that cannot be achieved in table or list forms. A hypothetical project is demonstrated to create such features as household incomes and demand points. Queries are then created to find optimal solutions for four location problems: (1) minimum distance, (2) maximum demands coverage, (3) maximum incomes coverage, and (4) optimal center.

The four location problems appear to vary in query results. Identifying which problem query is the best is out of the scope of this study. It depends on the preference of decision makers in terms of accuracy and simplicity/complexity and the availability of information. Nevertheless, a GIS is able to address more complicated queries once an appropriate query program has been created in the system.

Apart from locating and allocating retail sites, a GIS approach is adequate for other business and market strategies and analyses, such as market penetration, business forecast, consumer behavior/profile tracking and prediction, etc. Its potentiality in business application is still being explored. Yet, its usefulness in the construction industry is obvious since construction projects involve numerous spatial analyses for both technical and non-technical problem areas. In location selection (a non-technical area), the most time-consuming and tedious task in a GIS is probably the creation of detailed digital maps with features of every single point, line, and polygon (e.g., street, road, and demographic data). Notwithstanding, by use of such illustrative maps, decision makers can obtain very accurate solutions for problems.

CHAPTER 6: INTEGRATION OF GIS WITH DEA FOR SHOPPING MALL LOCATION SELECTION

6.1 Introduction

Site selection is critical for planning a real estate project. It is a core component of the pre-planning phase, after which the project life cycle will commence. In many cases, developers have to prioritize or select sites for investment development based on two reasons. First, they have a number of sites on hand available for development. Due to limited resources, they need to set the priority for developing these sites. Sometimes, they may need to select more profitable projects and withdraw less profitable ones owing to the viability of finance. Second, they may look for a new site to develop and have to select the best one from a pool of potential locations. Before making a decision on prioritization or selection, developers should identify the criteria for estimation and determine a method for comparing potential sites. Although this study deals with both selection and prioritization of sites, this study would raise discussion based on the term “selection” but this includes suggestions for the term “prioritization”. It is also noted that the current research is specific for real estate projects, but may act as a point of reference for other projects.

The study on location theory began in 1909 when Alfred Weber considered how to position a single warehouse so as to minimize the distance for several customers who patronized it (Weber, 1929). Since then, a lot of models have been built for selecting sites for storage, retail shops, parks, fire stations, hospitals, and so forth, where the location problems are not only spatial and temporal but also economical (e.g., Bechmann, 1999; Chan, 2001, Abbasi, 2003; Arampatzis et al., 2004). These projects involve different sets of selection criteria. For example, locating facilities (e.g., police stations or hospitals) has to consider how to offer acceptable services to residents with the minimal cost of locating the facilities, while locating retail outlets should focus on how to select a site with the maximal number of shoppers (Li. etc. , 2004).

Other than the use of simple methods, location selection can be more scientific. Mathematical models are one of the mainstream methods used for solving location problems. Basically, there are three kinds of mathematical models, which are: (1) static and deterministic location problems, (2) dynamic location problems, and (3) stochastic location problems (Owen and Daskin, 1998). Among all, the static and deterministic location problems are the most simple and can be solved by using linear models. Dynamic and stochastic models are more complicated and are more appropriate for addressing problems involving a more complex problem structure. In order to determine which kind of models to be used, one can refer to the nature of the location problem. Although linear models are commonly used to evaluate the performance of potential sites, the application of dynamic models is growing and is necessary due to the increasingly turbulent environment (Current et al., 1997). Since the environment of real estate is less complicated, static and deterministic models are sufficient for dealing with most of the real estate projects.

Many models derived from the abovementioned methods assume that the criteria to be measured are of equal importance. This can reduce the complexity of the decision problem but raise the possible deviation from accurate estimation. Unless the criteria are equally important in reality, weights have to be assigned to the criteria to determine their relative importance (Cheng and Li, 2004). This needs decision makers to assign weights to the criteria. Weights are usually assigned based on such simple methods as past experience or "gut feeling". Yet, these methods are argued to be not reliable. More scientific is to employ mathematical and statistical methods. A popular example of mathematical methods is the adoption of analytic hierarchy process (AHP) (Cheng and Li, 2001). This method involves the use of pair-wise comparison, which is argued to be time-consuming. An example of statistical methods is the use of regression models (Molenaar and Songer, 1998). Notwithstanding, solving regression equations need data from a sufficient large sample, which might be unavailable because decisions are always made by one or a small group of decision maker. On the other hand, assigning weights based on these methods are argued to be subjective. This study therefore introduces Data Envelopment Analysis (DEA), which is an objective method to assign weights to criteria and do not need a sample. DEA is a kind of multi-criteria decision-making methods and makes use of ratio analysis to solve location selection problems.

Another concern of this study is that the mathematical methods, including DEA, are not user-friendly in certain ways, especially when explaining to the senior management about the method used. With the emergence of geographic information systems (GIS), both spatial and non-spatial data can be handled simultaneously, resulting in its specific roles in data management and integration, data query and analysis, and data visualization (Li et al., 2003). A GIS combines spatial and non-spatial data to construct thematic maps depicting a variety of demographic information relating to population, housing, and economic activities. It helps to solve location problems and presents the results in visualized forms when necessary. Hence, this study aims at exploring the use of GIS for location selection problems.

In considering the above points, this study would like to present a new approach to site selection for real estate projects, i.e., a GIS-based site selection system. This system makes use of the GIS technology to incorporate the DEA method for locating the best site. The architecture of the DEA method and the GIS based site selection system is described in this study and a case study is presented to demonstrate the application of the system.

6.2 Necessity of Using DEA Method

As mentioned earlier, linear model is commonly used for site selection of real estate projects. A query against this approach is that it might involve subjective judgment on assigning weights to the selection criteria. For more objective evaluation, the Data

Envelopment Analysis (DEA) approach is recommended. The DEA method was created by Charnes, Cooper and Rhodes (1978). It enables the comparison of efficiencies of different systems, the so called Decision Making Units (DMUs), which have multiple inputs and multiple outputs (Wei, 1987; Hao et al., 2002). It is used for evaluating the relative performance of DMUs by means of comparing their "inputs" and "outputs" (Cooper et al., 2000). One of the benefits of this method is that users do not need to assign a weight to each criterion. Instead, weights are automatically computed by the DEA method. It has been used extensively in evaluating the efficiency of manufacturing product lines, schools, financial investment, and so forth.

There are many DEA models among which the most popular one is the C^2R (Charnes/Cooper/Rhodes) model (Charnes et al., 1978). In this model, it is supposed that the system has n DMUs, and each DMU has m inputs (X) and s outputs (Y). For each DMU, it has an input vector $X_j=(x_{1j}, x_{2j}, \ldots, x_{mj})^T$ and an output vector $Y_j=(y_{1j}, y_{2j}, \ldots, y_{sj})^T$, where x_{ij} is the score of input i for the DMU j, and y_{rj} is the score of output r for DMU j. The matrix structures of X and Y are shown below:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ y_{s1} & y_{s2} & \cdots & y_{sn} \end{bmatrix}$$

For each pair of input and output, there exists a corresponding weight. The quotation of the weighed sum of the outputs to the inputs is called the performance of the DMU, and it must be equal to or less than 1 in order to keep the normalization of DMUs.

The score of each DMU, which stands for its efficiency, can be obtained by computing the performance under the set of weights that maximize the DMU's performance while keeping that of other DMUs being equal to or less than 1. The mathematical model of this is shown in Figure6.1.

$$\begin{cases} \max \dfrac{u^T y_0}{v^T x_0} \\ \dfrac{u^T y_j}{v^T x_j} \le 1,\ j = 1,2,...,n \\ u \ge 0, v \ge 0, u \ne 0, v \ne 0 \end{cases}$$

Figure6.1: The mathematical model of a DMU

The DMU is evaluated as effective when its score is equal to 1 and as ineffective otherwise. Generally, effective DMUs represent better DMUs than ineffective ones. Yet, this kind of evaluation is too rough to compare between DMUs so that the concept of ideal DMU is introduced.

With respect to location selection, an ideal DMU is the one that adopts the lowest value of each input among all DMUs and the highest value of each output among all DMUs and that is subject to the same constraints as shown in Figure6.1. Obviously, the weights obtained from the ideal DMU are equitable to all DMUs, thus enabling the performance of the DMUs to be evaluated in a comparable way (Li et al., 2000). The model using the ideal DMU is called a uniform DEA model, which is adopted in this study.

Since location problems of real estate projects always involves multiple criteria, which can form inputs and outputs, the DEA method is able to compare potential sites since the best site is the site that can maximize the ratio of outputs to inputs. It is noted that these inputs and outputs can be spatial criteria as well as economical criteria. Hence, observable criteria, such as distance, demand cover, land value, and return on investment (ROI), can all be incorporated into the model. It can also be able to address temporal problems when time is considered to be a factor.

Use an example to illustrate the DEA method. Suppose a site selection project for a shopping mall from three potential locations. It is important to evaluate their performance based on a set of criteria. At first, we have to determine which criteria are inputs and which are outputs. In this example, the input criteria are land-value and number of households in 1km circle, while the output criteria are average spent money, ROI, and total income of the households. Then, data about these inputs and outputs for each site are collected, which are shown in Table6.1.

Table6.1: Inputs and Outputs for Candidate Sites

		Site A	Site B	Site C	Ideal Site
Inputs	Land-value ($\times 10^6$ \$)	45	60	55	45
	Households in 1km circle ($\times 10^3$)	120	105	105	105
Outputs	Average spent money ($\times 10^3$ \$)	60	65	70	70
	ROI (%)	10	12	9	12
	Total income ($\times 10^3$ \$)	400	350	380	400

According to the definition, the ideal site should have all the lowest values of inputs and all the highest values of outputs. As shown in Table6.1, these lowest and highest values are those cells with shaded background and form the ideal site that occupies the last column. Then the data of each site including the ideal site will be used to set the equations and form the uniform DEA model as shown in Figure 6.2.

$$\begin{cases} \max \dfrac{70u_1 + 12u_2 + 400u_3}{45v_1 + 105v_2} \\ \dfrac{60u_1 + 10u_2 + 400u_3}{45v_1 + 120v_2} \le 1 \\ \dfrac{65u_1 + 12u_2 + 350u_3}{60v_1 + 105v_2} \le 1 \\ \dfrac{70u_1 + 9u_2 + 380u_3}{55v_1 + 105v_2} \le 1 \\ \dfrac{70u_1 + 12u_2 + 400u_3}{45v_1 + 105v_2} \le 1 \end{cases}$$

Figure 6.2: A uniform DEA model

In Figure 6.2, the objective is set to maximize the ratio of outputs to inputs for the ideal site and four constraints for the three potential sites and the ideal site. After these equations are solved, we could get a set of common weights: u_1, u_2, u_3 and v_1, v_2. By applying these common weights on the equations of the potential sites, their performance could be calculated and the one with the highest ratio value should be the best site. As each site has a ratio value, developers can also prioritize these sites for the purpose of allocating their investment.

6.3 A GIS Based Site Selection System

As shown in the previous example, one of the inputs is the number of households in 1km circle. For this spatial data, a great deal of work is needed to obtain useful data. Other than the demand of household data in this area, evaluators have to determine how to exactly measure a circle with a radius of one kilometer from each potential location. This would be difficult if it is done manually on the street. With the help of a GIS, this arduous task can be done easily. Once a street map has been stored as a layer in the GIS, a circle can be drawn in it. If we have another layer with household data, the total number of households can be calculated automatically by the system. Basically, a GIS software program should have three components: (1) tools for entering and manipulating data, (2) a database management system for managing data, and (3) a graphical user interface (GUI) for viewing purpose (GIS, 2003). This is consistent with the three-step schema as described by Arampatzis et al. (2004), which are (1) the database, (2) a number of mathematical models, and (3) the presentation of model results through such outputs as thematic maps, figures, tables, and diagrams. For the more complicated DEA-based approach to location selection, extensive calculation is necessary to solve the DEA equations. Based on these considerations, a GIS based site selection system that incorporates the DEA method was planned and a prototype system has been developed. Details of which are shown in the following subsections.

6.3.1 Development Environment

Several basic architectural considerations are outlined: (1) Microsoft Windows 2000 is adopted as OS (Operating System), (2) MapObjects – Windows Edition 2.2 provided by ESRI (Environmental Systems Research Institute) is adopted as the GIS component (ESRI, 2004), and (3) Microsoft Visual C++ 6.0 is used as the development environment for the application program.

6.3.2 System Architecture

The architecture of the system can be divided into three layers: presentation layer, logic layer, and data layer (as shown in Figure6.3). In the presentation layer, there are two viewer modules (Map Viewer module and Location Result Viewer module), which are due with the user interface. The logic layer commands the tasks of loading the map, setting the potential (candidate) sites, evaluating the potential locations by the incorporated calculation models, and sorting them to be viewed finally. The data layer consists of the GIS database and the model database. The GIS database contains the spatial database and the relational database, in which the data regarding base-map, facility, population, and so forth are stored. The model database stores the linear model and the uniform DEA model.

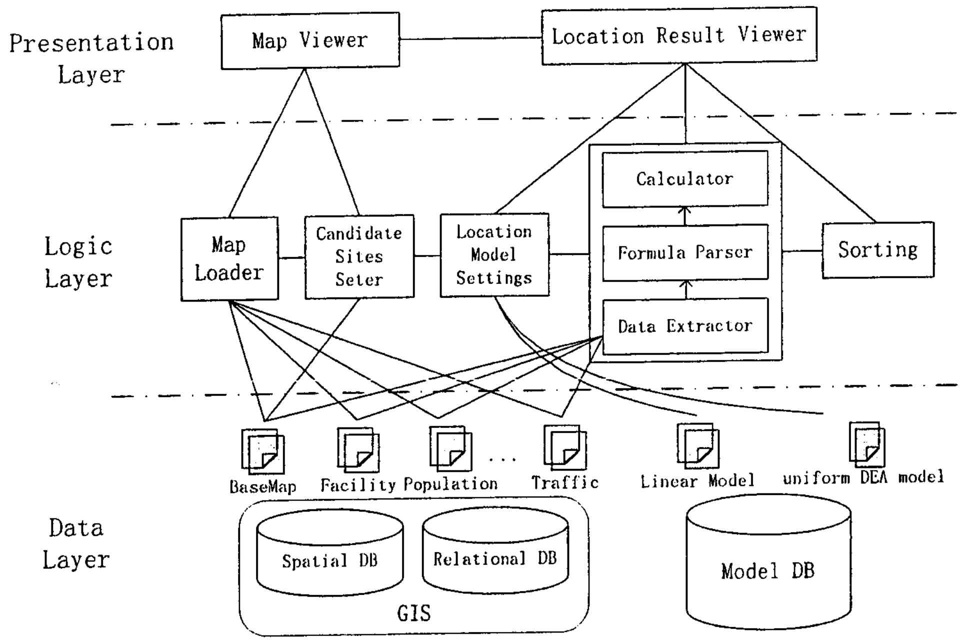

Figure 6.3: The architecture of the DEA and GIS based site selection system

In a GIS, queries are created for finding solutions that can address location problems. Suppose that a user would like to calculate the number of households in 1km circle for three locations. First, the street map is loaded on the map viewer and the three sites are selected on the map. With the search-by-distance function provided in the MapObjects component, three circles can be drawn around each location with a radius of 1km. The user then sets the query to calculate the number of households within each circular area.

This is achieved by the Data Extractor module where the data needed for the linear model will be extracted and calculated automatically. The uniform DEA model can help address more complicated problems with the data needed for calculations being extracted and calculated automatically. The user sets the calculation formulas, while the system will get the data from proper layers. Then the expression calculator will replace all the variables with proper numerical values for computation. Moreover, the user can define new inputs and outputs for the uniform DEA model by specifying proper map layers, conditions, radius values, and calculation formulas. With this system, not only the performance but also the priority of potential sites can be determined and visualized on the location result viewer.

6.3.3 Considerations for Using the Uniform DEA Model

This subsection will introduce the uniform DEA model in the system. As shown in Figure 6.4, the criteria (or the influential factors) are selected from a list in a pop-up window which shows the interface for setting the inputs and outputs for the problem. Users have to select the inputs and outputs. This is a user-friendly window and users only need to use the arrow buttons in the middle to select and delete inputs and outputs. As in Figure 6.4, the system has stored a lot of criteria in the "All Factors" column. This gives flexibility to users when they need to choose various criteria for different projects. Once the data has been retrieved, computation is undertaken automatically. However, it is also essential to know how the data can be obtained and how they work within the system.

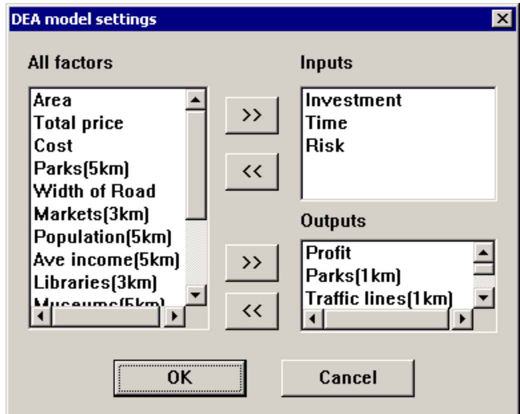

Figure 6.4: Interface of setting inputs and outputs

Data are basically provided by users. For example, data, such as ROI and other financial information, with respect to a specific organization are obtained from that organization. Data, such as households or demographic information, with respect to a region can be obtained from governmental bodies (e.g., statistical department) or public surveys companies. Spatial data for a region, such as parks, streets, railways, etc., are usually available from existing commercial GIS databases. In order to increase the quality of the decision, objective data are more appropriate. However, criteria, such as the degree of risk, would involve subjective measures, of which the scales to be used must be determined cautiously. Due to the dynamic nature of the data set (i.e., change over time), update of data must be undertaken regularly to make sure the accuracy of the decision to be made. For example, the number of households in an area will change from time to time, while projected profit for next year may be different from this year. For some criteria, a monthly update is needed, while for some others, a yearly update is suggested. Different criteria entail various update schedules, which also have to be determined carefully.

After the data has been stored in the GIS database, users need to set the location sites so that the system can retrieve relevant data from the database. In this GIS system, users can set the locations just by clicking a point for each location on the map, where users can edit the name and the position of them, or even delete them. With the map browser tools, such as zoom-in and zoom-out, users can perform this task on the system interactively. The whole system makes use of the GIS technology to streamline the process for data storing and retrieving, mathematical calculations, and results presentation. Various queries can be set to solve different decision problems.

Similar to the scenario functions of Arampatzis et al. (2004), the GIS system involves three main decision support functions, which are management, analysis, and comparison. Decision support management offers users with data management capabilities to create new criteria and retrieve previous stored criteria. A popup window is built so that the creation and retrieval of criteria is simple and straightforward. The most important is that users must define new criteria properly and determine carefully of what criteria to be employed. Decision support analysis corresponds to the analysis and presentation of computational results using suitable outputs including thematic maps, diagrams, tables and reports, which are printed out with the print function. To improve its functionality, outputs must be sufficiently "vibrant" in the sense that view functions such as drill-down, zooming, and configuration are all possible. Decision support comparison permits the evaluation and comparison of alternative locations. Since the DEA method was installed, comparisons among locations can be performed immediately and the results are included in the report.

6.4 An Application Project

This application is about an investment project that selects a location for a shopping mall. Initially, there were three potential sites (A, B, and C) being under consideration. These sites were situated in locations that were not equivalent in terms of total investment and projected profits. For example, sites B and C were located in prime areas and their investments were expected to be more. Moreover, sites A and C were on areas that had less amounts of households, and thus profits that were projected from them were less than that of site B. Hence, selecting among these sites was not a straightforward decision because each site had specific aspects as compared to others. A GIS helped to make the decision by incorporating all necessary considerations together.

As stated previously, the first step of a GIS was to develop map layers. Our GIS based site selection system has already established the layers' database for real estate projects. In this system, there are map layers about parks, traffic lines (streets, roads, and railways), supermarkets, and clinics. For real estate projects, additional data are necessary, such as the projected profit and the duration of the project. Thus, the data on these temporal and economical aspects have to be estimated or collected from other sources. Additional data about total investment amount, duration for completion (time), profit, and risk were stored in the GIS database (as shown in Figure 6.4) to make it more complete for solving problems with respect to real estate projects. The system is ready for use by simply storing extra data, selecting the inputs and outputs, and setting the queries.

For this project, eight criteria were selected, which were total investment amount, time, risk, projected profit, the number of parks, supermarkets and clinics within 1km circle, and traffic lines. Table 6.2 lists the data of some of these aspects for the potential sites. Due to the differences between these sites in terms of their difficulties in construction and surrounded environment, their total investment, profit, time, and risk differentiated to a certain extent. For instance, Site A had the lowest amount for total investment and the shortest duration for completion. Site B had the highest amount of projected profit and the lowest risk. These formed the ideal values for the uniform DEA model's computation.

Table 6.2: Temporal and Economical Data of the potential Sites

	Site A	**Site B**	**Site C**	**Ideal Site**
Total Investment	$21,300,000	$28,980,000	$28,500,000	$21,300,000
Profit	$3,900,000	$6,300,000	$3,420,000	$6,300,000
Time	48 months	66 months	60 months	48 months
Risk	63.4	59.8	70.7	59.8

The eight criteria were expected to be crucial but with different degree of importance. In addition, for applying DEA, it is essential to determine which criteria are inputs and which are outputs. In this project, those criteria of which their values were preferred to be maximized were selected as outputs, while those of which their values were preferred to be minimized were selected as inputs. The ideal site column in Table 6.2 disclosed input and output criteria. Finally, total investment, time, and risk were selected as the inputs, while profit, the number of parks, supermarkets and clinics within 1km circle, and traffic lines were outputs.

Figure 6.5 illustrates the geographical nature of the three potential sites and the circular area covered by each site. This figure was formed by combining several layers together with the layer of the three potential sites. First, there was a map layer showing the contour lines of the areas covered by this project. Second, there was a layer showing streets, roads, and so forth, which surrounded the three locations. Third, there was a layer illuminating households in this area in terms of shaded areas drawn on the layer. Other layers were also incorporated showing such criteria as park, clinic, commercial center, market, and library.

After locating and inputting the map positions of the potential sites into the GIS system, the query could be set. In this project, the query was to locate the best site by maximizing the ratio value of outputs to inputs. Since this query was performed by the DEA model, users did not need to specify the query equations for calculation because the DEA model had been built in the system. The system will automatically analyze the data and compute the results once the map positions of the potential sites have been identified on the screen and a command for executing the query has been set.

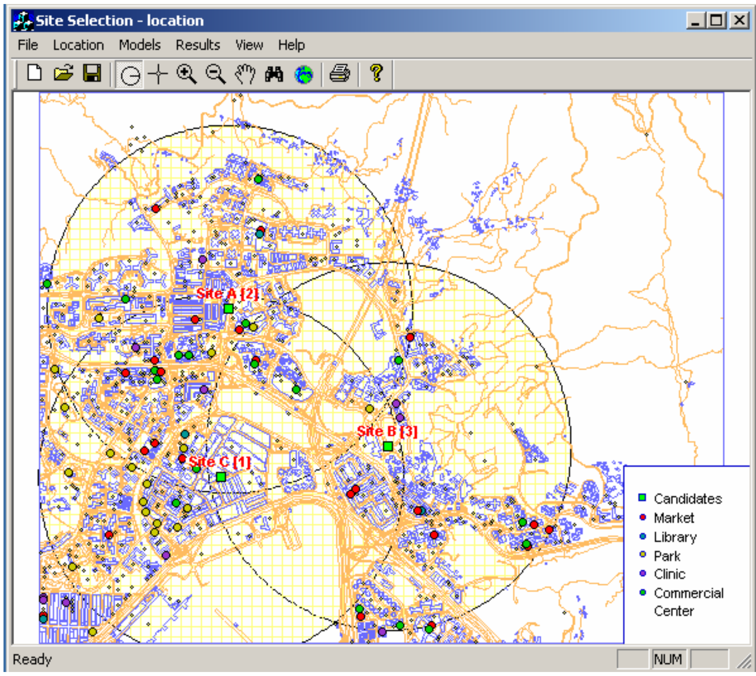

Figure 6.5: The geographical nature of the potential sites

After the system had calculated the score for each potential site by means of the uniform DEA model, the results were shown on a result viewer similar to the format shown in Table 6.3. In this project, site C had the highest score (0.513), followed by site A (0.494) and site B (0.389). Their priority had been set. If only one site be selected, then site C should be chosen first. If all three sites are to be built, the user should follow the order from the one with the highest score to the one with the lowest score.

Table 6.3: The Results of Uniform DEA Model

	Site A	**Site B**	**Site C**
Score	0.513	0.494	0.389
Priority	1	2	3

Note: Keep three decimal places.

The advantage of this GIS-DEA system is that it allows changes (addition or deletion) of data and/or criteria. With any addition or deletion of data and/or criteria, the system will calculate new sets of results in a few seconds. If necessary, users can compare between different sets of results to determine their strategies for developing the sites. For example, if the addition of a criterion has changed the rank of the sites, the user must determine whether this criterion is to be adopted. With this view, it is believed that decision problems and models are always involved in substantial subjective judgments. However, the process of such subjective judgments must be carefully managed to reduce biases created during the process.

The GIS-DEA system makes use of two-dimensional layers. This would be useful to projects where height of the spatial area is not an issue for a location selection problem. For example, if the potential locations are on a rather flat area, then two-dimensional layers are sufficient. In contrast, if the potential locations are on different heights above sea level, then three-dimensional layers are more appropriate. For example, if prime areas are at the mid-level of a hill, the projected profit of a location at the mid-level can be set higher. Although this will increase the complexity of the problem structure, the accuracy of the decision will be improved. For extra benefits to the GIS-DEA system, three-dimensional layers will be the next stage of research to be explored in the next stage of this study.

6.5 Conclusions

This study introduces the GIS based site selection system. This system incorporates the DEA method for real estate projects' location selection. A GIS helps users organize and combine the spatial, temporal, and economical information. The DEA method builds in the query for selecting locations by maximizing the ratio of outputs to inputs. The GIS approach is able to solve site selection problems visually, while the DEA method is argued to be objective. Another benefit of the DEA method is that it will automatically calculate the weights for the criteria. Once the data are available and multiple layers are constructed in the system, query can be set and results can be obtained in a few seconds after the potential sites have been positioned on the screen. The study has demonstrated an application to illustrate this user-friendly system by selecting locations for a residential building project. The prototype of this system has been developed and the next stage of application is to test this system with more real estate projects. However, this study does not intend to express that this system is the best to address all decision problems. The study aims to introduce an alternative approach for those who are involved in site selection for real estate projects.

CHAPTER 7: CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

This study involves the review of existing methods for location selection. Based on the literature review, the DEA model and the AHP/ANP model are selected and used to develop solutions for location selection problems of real estate projects, especially shopping mall location selections which are the main problem in the research. The GIS system is also used as a platform to implement the location selection models. Results of the study indicate that the DEA model and ANP model are appropriate for solving location selection problems in real estate.

From this study, the following conclusions can be drawn:

1. Because of the unique nature of real estate location selection problems, factors involved can be either quantitative or qualitative, and weightings related to the factors may vary from problem to problem. From experimental results, this study identified that simple location models previously developed may not be suitable for solving location selection problems for real estate projects.

2. One of the major considerations of whether to undertake a project investment in a real estate project is to determine if the location is valuable for investment. In the current practice, selecting locations for real estate projects are rudimentary and

experiential. The GIS and ANP approaches are usable and effective tools to analytically solve location selection problems for real estate projects.

3. An ANP (analytic network process) approach is a useful tool for location selection which focuses on how to identify decision criteria (by structuring a decision model) and how to weight the criteria (by use of pair-wise comparison). As a new and robust multi-criteria decision-making method (MCDM) which can produce the most comprehensive analytic framework for solving societal, governmental, and corporate decision problems. Compared with AHP system, the ANP is a powerful tool if the decision model is substantially affected by interdependent relationships.

4. Geographic information systems (GIS), taking the advantage of information technology, enable the handing of both spatial and non-spatial data, leading to its specific roles in data management and integration, data query and analysis, and data visualization. (Li et al., 2003)

5. GIS approach can combine spatial (geographical) and non-spatial (market-oriented) data to construct thematic maps depicting a variety of demographic information relating to population, housing, and economic activities. Especially, the visualized information that can be easily understood and analyzed by decision makers and that cannot be achieved in table or list forms.

6. The usefulness of a GIS approach in the real estate industry is obvious since real

estate projects involve numerous spatial analyses for both technical and non-technical problem areas. In location selection (a non-technical area), the most time-consuming and tedious task in a GIS is probably the creation of detailed digital maps with features of every single point, line, and polygon (e.g., street, road, and demographic data). Notwithstanding, by use of such illustrative maps, decision makers can obtain very accurate solutions for problems.

7. The integration of GIS and DEA enabled us to develop a system which combines the advantages of DEA in its mathematical modeling capacity of location selection problems, and the user-friendliness of GIS.

8. A hypothetical project demonstrated to create such features as household incomes and demand points which find an optimal solution for four location problems: (1) minimum distance, (2) maximum demands coverage, (3) maximum incomes coverage, and (4) optimal center. However, identifying which problem query is the best is out of the scope of this study. It depends on the preference of decision makers in terms of accuracy and simplicity/complexity and the availability of information. Nevertheless, a GIS is able to address more complicated queries once an appropriate query program has been created in the system.

On the other hand, this study can be further improved from following aspects. First, there is a need to further investigate and identify clusters of criteria used in the location selection of different types of real estate investment projects. For example, there is obvious difference in the criteria used in residential, retailing projects and shopping mall. Second, there is a need to compare the capacity and usefulness of the proposed location selection model which combines ANP and DEA by comparing the results of this model with those from other location selection methods. In addition, although DEA has been used to determine weightings of factors, it is difficult to formulate the objective function to include all factors used in a location selection problem. Therefore, the example used to demonstrate the DEA method is a simplified one. There is a need to further investigate how to incorporate all factors used in a location selection problem into the objective function needed in the DEA method. Finally, the GIS-DEA system only applied the two-dimensional GIS system. In the next stage of study, there is a need to use three-dimensional GIS to further explore the benefit of the 3D GIS system.

Further more, the study can be improved by applying the sensitivity analysis to evaluate the validity of the results from DEA to ensure that DEA is suitable for application in solving location selection problems of shopping mall investment projects.

Location selections problems are often involve many qualitative factors which cannot be easily incorporated into the decision models. As part of plan for future study, there is a need to further extend the decision models developed in this study by effectively integrating both quantitative and qualitative factors involved in the location selection problems.

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Appendix 1: Data Envelopment Analysis Model Example

To extending the previous example of selecting the best performer from five shopping complexes, recall the mathematical model as follows:

Mathematical model:

$P_i = \sum (w_k y_{ik}) / \sum (w_j x_{ij})$

Subject to:

$0 <= P_i <= 1$

$w_k, w_j => 0$

Inputs:

x_1 = the number of households in the area

x_2 = the number of shopping complex in the area

Outputs:

y_1 = the average monthly spending in the targeted shopping complex

y_2 = average disposable income in the area (monthly)

y_3 = average savings of households in the area (monthly)

Weights:

w_1 = the weight assigned to the number of households

w_2 = the weight assigned to the number of shopping complexes

w_3 = the weight assigned to the average monthly spending

w_4 = the weight assigned to the average disposable income

w_5 = the weight assigned to the savings

Appendix Table 2 exhibits the data of the inputs and outputs for the five shopping complexes. By incorporating these data, we can establish the mathematical equations as shown below:

- $0 <= (w_3*0.45 + w_4*5.0 + w_5*0.1) / (w_1*78 + w_2*2) <= 1$
- $0 <= (w_3*0.78 + w_4*6.2 + w_5*0.15) / (w_1*80 + w_2*3) <= 1$
- $0 <= (w_3*0.80 + w_4*6.0 + w_5*0.12) / (w_1*50 + w_2*1) <= 1$
- $0 <= (w_3*1.20 + w_4*5.3 + w_5*0.10) / (w_1*90 + w_2*4) <= 1$
- $0 <= (w_3*0.70 + w_4*4.5 + w_5*0.14) / (w_1*75 + w_2*2) <= 1$

Appendix Table 2. Data of the inputs and outputs for the five shopping complexes

	x_1 (,000)	x_2	y_1 ($ in million)	y_2 ($ in million)	y_3 ($ in million)
P_1	78	2	0.45	5.0	0.1
P_2	80	3	0.78	6.2	0.15

P_3	50	1	0.80	6.0	0.12
P_4	90	4	1.20	5.3	0.10
P_5	75	2	0.70	4.5	0.14

To calculate P_1, we set: $w_1*78 + w_2*2 = 1$, and so forth for other P_i. All computations (including those in Appendices 2 and 3) were performed by the new version of Lingo8.0 (2003). Appendix Table 3 summarizes the results and indicates that Shopping Complex 3 is the best location as it has the maximum possible performance. It is noted that this demonstrated example does not judge if the weight results are realistic. For example, in Shopping Complex 2, the weight attached to savings is much larger than those attached to other variables, implying that the effect of savings is acute. These weights seem unrealistic. Yet, the variable with the largest weight in the best performer, Shopping Complex 3, is the average disposable income, which is expected to be a reliable performance indicator. In addition, other variables are comparable in terms of their weight ratios, supporting the decision to make.

Appendix Table 3. Results of the performance of the five shopping complexes

	Shopping Complex 1	Shopping Complex 2	Shopping Complex 3	Shopping Complex 4	Shopping Complex 5
w_1	0.013	0.013	0.020	0.011	0.013
w_2	0	0	0.020	0	0
w_3	0	0	0.038	0.694	0
w_4	0.107	0	0.161	0	0
w_5	0.014	5.208	0.022	0	5.556
Performance	0.534	0.781	1	0.833	0.778

Note: w1 to w5 are the weights attached to the inputs and outputs of the shopping complexes.

Appendix 2: Deterministic Model Example

To extend the previous example of selecting a new outlet for a chain retailer, suppose it has four locations to select. Recall the objectives as follows:

- Minimize $\sum_i \sum_j d_{ij}u_{ij}$
- Maximize $\sum_j g_j y_j + \sum_j g_j z_j / 2$

The problem may also be referred to as a vertex P-center problem. Instead of finding a minimax solution, this research used an alternative method, which is to perform two computations by setting one of the two original objectives as the primary objective and the other as a constraint in each computation. Two sets of results would then be obtained. This method is also appropriate for solving more maximal and minimal objectives.

Appendix Table 4 exhibits the data obtained for the four locations, while Appendix Table 5 shows the distance between each location and each demand node.

Appendix Table 4. Demand data at the four demand points

	g_1	g_2	g_3	g_4
Demand (number of household)	2000	3000	3500	2500

Note: x_i is the potential location i (where i = 1, 2, 3, 4).

Appendix Table 5. Distance between each location and each demand node

d_{ij} (in meter)	1	2	3	4
1	200	250	600	620
2	450	200	430	580
3	580	500	250	500
4	470	620	600	250

Other information being furnished is shown below:

- Demand node 1 can patronize locations 1 and 2.
- Demand node 2 can patronize locations 1, 2, and 3.
- Demand node 3 can patronize locations 2 and 3.
- Demand node 4 can patronize locations 3 and 4.
- Only demand node 2 has no tie between competitors and the potential store.

Computational results indicate that location 1 is the best among the four locations for objective 1 (with a minimal objective value of 20 units), while location 3 is among the best for objective 2 (with a maximal objective value of 90 units). Results also indicate that if location 3 is chosen in objective 1, it has a value of 25 units. Additionally, if location 1 is chosen in objective 2, it has a value of 50 units. Then, we can calculate the ratio value of each of the two locations with respect to the two objectives. Specifically, we placed the objective value with respect to objective 2 as the numerator and that with respect to objective 1 as the denominator. The larger the ratio value, the better is the location. As a result, location 1 has a ratio value of 2.5, while that of location 3 is 3.6. Therefore, location 3 has a better value and should be selected. Preliminary results further indicate that location 3 would mainly serve for the demands at nodes 2 and 3 (which were 430m and 250m away from the location respectively). Hence, the company can formulate strategies to: (1) maximize its attraction at demand nodes 2 and 3 (at demand node 3 it has other competitors), and (2) enhance its attraction to other demand nodes especially demand node 4 that originally can patronize location 3.

Appendix 3: Dynamic Model Example

Suppose that a chain department store retailer would like to open a new outlet. It realized that demands at different demand points changed from time to time. It would like to know at which period they should open a new outlet in order to achieve maximal coverage of demands. Recall the objective as follows:

- Maximize $\sum_j \sum_t g_{jt}y_{jt} + \sum_j \sum_t g_{jt}z_{jt} / 2$

This simple dynamic model can be solved as a deterministic model. Appendix Table 6 exhibits the known demand data for three future periods. The table indicates that demand nodes 1 and 4 have a fast growing demand from period 1 to period 2 (demand in node 1 is growing four times faster than node 4), but their rate of growing is decreasing from period 2 to period 3. Demand node 2 has a steady growing in demand, while demand node 3 has no increase in demand at all.

Appendix Table 6. Demand data obtained for three periods

(number of household)	g_1	g_2	g_3	g_4
Demand at period 1	2000	3000	3500	2500
Demand at period 2	4000	3200	3500	3000
Demand at period 3	4800	3400	3500	3200

Other information being furnished is shown below (the same as previous example in Appendix 2):

- Demand node 1 can patronize locations 1 and 2.
- Demand node 2 can patronize locations 1, 2, and 3.
- Demand node 3 can patronize locations 2 and 3.
- Demand node 4 can patronize locations 3 and 4.
- Only demand node 2 has no tie between competitors and the potential store.

By assuming other things being unchanged, we can compute the optimal objective values for the three periods. Computational results indicate that location 2 should be chosen and an outlet is most appropriate to operate in period 3 (optimal objective value = 117 units).

Suppose that the company also realized that the later the opening of the outlet, the more the cost that it had to incur. The objective is then changed to:

- Maximize $\sum_j \sum_t (g_{jt}y_{jt} + \sum_j \sum_t g_{jt}z_{jt} / 2)c_t$ (where c_t is the percentage reduction due to cost at time t)

Such an additional cost was assumed to be 50 percent of the objective value it has for period 1 and to increase by 25 percent from one period to another. Computational results indicate that by attaching a cost to the time effect, the decision has to be changed to location 3 (optimal objective value = 45 units) and the outlet is best to be open in period 1.