APPLICATIONS OF VECTOR OPTIMIZATION PROBLEMS

BY

VANDANA BAGLA

UNDER THE SUPERVISION OF

DR. ANJANA GUPTA

Delhi Technological University (D.T.U.), DELHI

Submitted

in fulfillment of the requirement of Research Summary

to the

TEERTHANKER MAHAVEER UNIVERSITY

MORADABAD
SUMMARY

OF

RESEARCH WORK
The research work titled “Applications of Vector Optimization Problems” focuses on various perspectives of formation and solutions of Multi Criteria Decision Making (MCDM) problems. Over the last few decades, various new approaches have been developed and the methodologies of decision making processes have been improving gradually. Decision-making approaches are broadly employed for the selection of the best compromise solution, as any alternative cannot usually excel in all the criteria under consideration simultaneously. Besides, the real criteria values by which a decision is made, the selection of the best solution also depends on the decision maker’s individual preferences. Traditional decision making processes and models are falling behind in the fast pace of expedition. Although mathematical advances have been made in this area, these research areas are still contemporary and innovative. In this study, integrated solution methodologies for general MCDM problems are developed based on various MCDM approaches. Model-based MCDM is investigated, with the focus being on improving and applying approaches based on interactive multi objective optimization methods. In addition to the methodological aspects, there has been a focus on applying the interactive multi-objective optimization to the application areas that contain complex processes and conflicting targets, which have gathered increasing interest of modeling and optimization during recent years. The contribution of this thesis lies in a state of decision making from the applications in various scenarios taken up during the research. In this work, a new approach to decision making has been introduced that facilitates fast and reliable decisions. It enables pair-wise comparisons with necessary sagacity to obtain a clear and unambiguous conclusion.
Organization Of The Thesis

The thesis consists of eight chapters followed by

References and Bibliography
Contents

1 Introduction 8
   1.1 Literature Review ................................................. 8
   1.2 Introduction to MCDM Methods .............................. 9
      1.2.1 Analytical Hierarchy Process (AHP) ..................... 10
      1.2.2 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) ............................. 10
      1.2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ........................................ 11
      1.2.4 Rank Order Centroids (ROC) ............................. 12
      1.2.5 Ratio Method ............................................. 12
      1.2.6 Lexicographic Approach .................................. 13
      1.2.7 Weighted Penalty Method ................................. 13
   1.3 Publications ...................................................... 14

2 AHP Based Assignment Model For Allotting Parking Slots To Different Localities 15
   2.1 Introduction ..................................................... 15
   2.2 Problem Description and Mathematical formulation ........... 16
   2.3 Solution Procedure ............................................. 17

3 Site Selection Using Optimization Techniques 18
Chapter 1

Introduction

This chapter is introductory and covers review of literature since 20\textsuperscript{th} century till date. A brief preamble of Multi Criteria Decision Making (MCDM) methodologies is also included.

1.1 Literature Review

The study of decision problems has a long history and in the last few decades, it has been one of the major research field in optimization discipline. A preeminent work has been carried out in 20\textsuperscript{th} century in field of optimization theory. The mathematical modeling of these decision making problems gained momentum with monumental contributions of various eminent economists and mathematicians.

In context of MCDM problems, Major advances have been recorded since 1980s. Saaty(1980) introduced the Analytic Hierarchy Process (AHP), which brought evolutionary advances in MCDM approaches. Saaty being placed in Fortune magazine, is visibly one of the most successful people in MCDM. AHP, developed by Saaty is one of the most popular techniques used by the researchers and practitioners. Another useful technique, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was developed by Hwang and Yoon(1981) and it is a popular ap-
proach to MCDM problems. In early 1980s, Brans(1982) laid fundamentals of Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), which is a part of outranking methods used as decision-aid in various MCDM problems. Considerable work was carried out for more than a decade to bring out various versions of PROMETHEE by Brans et al.(1982; 1984; 1988; 1992; 1994; 1996).

Saaty & Takizawa(1986) revised AHP in their study so that it could handle the non-linear hierarchies. Edwards & Barron(1994) first propounded Multi Attribute Global Inference of Quality(MAGIQ) which was based on rank order centroids to assign attributes’ weights. Carlsson & Fuller(1995) in mid 1990s introduced interdependency concept into MCDM which later on was improved by Ostermark(1997).

Saaty(1996; 1999) developed the Analytical Network Process (ANP) by the end of 20th century, which is a more general form of AHP. Numerous other credible approaches have been cultivated and fostered till date, by eminent researchers in the specified field.

1.2 Introduction to MCDM Methods

MCDM models are divided into two groups of Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). With regard to the subject under consideration, the problems of decision making in this research cover both MADM and MODM models. By considering the various techniques of MCDM Models, some of the MCDM methods used in the present work are: Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Multi Attribute Global Inference of Quality (MAGIQ), Simple Additive Weighting (SAW), Ratio Method, etc.
1.2.1 Analytical Hierarchy Process (AHP)

The formulation of AHP given by Saaty(1980) emerged as a paradigm for decision making scenarios categorized under MADM. It is based on the well-defined mathematical structure of consistent matrices and their associated eigenvector’s ability to generate true or approximate weights. AHP can be considered to be both a descriptive and prescriptive model of decision making and it is perhaps, the most widely used decision making approach in the world today. Its validity is based on the many thousands of actual applications in which the AHP results are accepted and used by the aspirants. It is an approach to decision making that involves structuring multiple judgment criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives. It provides a comprehensive and rational framework for structuring a decision problem for representing and quantifying its elements. The outcome of AHP is a prioritized weighting of each decision alternative. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way.

1.2.2 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

PROMETHEE, an outranking decision making technique, was introduced by Professor Jean-Pierre Brans(1982) in 1982. At that time he proposed only the basic PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking) versions. Soon thereafter he started working with Bertrand Mareschal(1984) and they proposed Graphical Analysis for Interactive Assistance (GAIA) method as
a descriptive extension of PROMETHEE in 1988. The visual interactive module GAIA provides a marvelous graphical representation supporting the PROMETHEE methodology and it is one of a very few effective descriptive MADM methods till date. PROMCALC (later PROMCALC-GAIA) was one of the first truly interactive software with a strong emphasis on user interface, graphical representations and sensitivity analysis. The PROMETHEE method is based on mutual comparison of each alternative pair with respect to each of the selected criteria. In order to perform alternative ranking by the PROMETHEE method, it is necessary to define preference function $P(a, b)$ for alternatives $a$ and $b$ after defining the criteria. Alternatives $a$ and $b$ are evaluated according to the criteria functions. It is considered that alternative $a$ is better than alternative $b$ according to criterion $f$, if $f(a) > f(b)$. The decision maker has the authority to assign the preference to one of the alternatives on the basis of such comparison. The preference can take values on the scale from 0 to 1.

### 1.2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a MADM method to identify solutions from a finite set of alternatives. As suggested by Hwang and Yoon(1981), a MADM problem may be viewed as a geometric system in which the $m$ alternatives that are evaluated by $n$ attributes are similar to $m$ points in a $n$ dimensional space. Therefore, the most preferable alternative should be the point in that space that is nearest to the ideal solution and farthest from the worst solution.
1.2.4 Rank Order Centroids (ROC)

This method is a simple way of giving weights to a number of items ranked according to their importance. The decision-makers usually can rank items much more easily than giving weights to them. This method takes those ranks as inputs and converts them to weights for each of the items. The term ‘Rank Order Centroid’ was coined by Barron and Barrett(1996) who also argued for its use in MADM problems. The idea is to convert ranks into values that are normalized on a 0.0 to 1.0 interval scale. As proposed by James D. McCaffrey(2005), ROC is a MADM technique based on a hierarchical decomposition of comparison attributes. It has features similar to AHP and is used to assign a single, overall measure of quality to each member of a system having arbitrary number of comparison attributes. This technique uses rank order centroids to assign normalized numeric weights to the comparison attributes as an overall measure of quality with reference to a set of evaluation criteria. MAGIQ was originally developed to validate the results of AHP by adopting a comparatively simplified course of action and the technique has produced highly useful results in practice.

1.2.5 Ratio Method

The Ratio Method is another simple way of calculating weights for a number of critical factors. A decision-maker should first rank all the items according to their importance in the preferred domain. The next step is giving weight to each item based on its rank in the interval \([10, 90]\). Here lowest ranked item will be given a weight of 10 and rests of the items are rated in multiples of 10 based on the preferences given by decision maker. For example if item \(II\) is five times more important to item \(I\) (the lowest ranked item), then item \(II\) is provided with a rating 50. The last step is normalizing these raw weights as proposed by Weber & Borcherding(1993).
1.2.6 Lexicographic Approach

Multi-objective optimization consists of optimizing a number of objectives that are usually conflicting. One way to tackle MODM problems is the lexicographic method. Here each objective is optimized one at a time subject to a pre-defined ordering established by the decision makers. It is important that the decision-maker must express preferences in order to establish the ordering and the performance of the method is vulnerable to the priorities given to various objectives. The single objective problem taking into account the most prioritized objective is solved, subject to given constraints by usual methods ignoring rest of the objectives. The problem is reconstituted considering the next prioritized objective with the previous solution as an added constraint. The process is repeated until all the objectives are dealt one by one adding the previous solutions in the constraint inequations. The approach is useful while dealing with few objectives (two or three) but the procedure may be lengthy when number of objectives exceed.

1.2.7 Weighted Penalty Method

While solving the MODM problems for a variety of parameters, scalarization is the most practical and feasible approach. Several possible solutions are generated depending on the priorities provided to various objectives. In the last decades, the main focus was on finding one optimal solution to such problems by interactive methods(1999; 1995) but now due to availability of much advanced application software, it is possible to represent the whole efficient set without much manual efforts. The decision maker gets a better insight to the problem structure by visualizing the whole solution set at a stretch. A wide variety of scalarization methods exist based on which one can assemble a MODM problem into prioritized single objective problem. In this work, a Weighted Penalty Cost Approach to put restrictions
on assignments, apart from achieving a prioritized efficient solution by exercising priorities to preemptive factors, has been employed.

1.3 Publications

The subject matter of the thesis is published / under publication in the form of following research papers worked out by the author.


Chapter 2

AHP Based Assignment Model
For Allotting Parking Slots To
Different Localities

2.1 Introduction

This chapter propounds a multi-criteria decision-making assignment model to allocate appropriate parking slots to various localities. An algorithm is developed that allows the consumers to choose the most suitable car parking according to their requirements. Due to growing population and a consequent increase in number of vehicles, the problem of parking personal vehicles is becoming explosive. Parking has been widely recognized to be an important transportation policy issue in the broad context of the transportation-land use relationship. All the aspects of sharing of parking slots are visualized subject to land availability. An effective resolution is suggested by framing a bi-objective problem to minimize the weighted cost and maximum distances traveled by the residents. MADM technique, Analytic hierarchy process (AHP) has been used to rank various relating attributes. MODM
model ‘Weighted Penalty Method’ is used for scalarization purpose.

2.2 Problem Description and Mathematical formulation

Suppose there are $m$ localities and $n$ available parking slots. Each of the locality is to be allocated with a parking slot subject to the conditions that development cost of the prescribed parking slot should be minimized, traveling distance should be minimum and the prescribed parking slot should justify the requirements of the locality. For $m > n$, available parking slots can be shared by aspiring localities and for $m \leq n$, no sharing is required.

Let the localities $l_i$ ($i = 1, \ldots, m$) are to be allocated with $p_j$ ($j = 1, \ldots, n$) parking slots. Suppose $a_i$ be the requirement of a particular locality $l_i$ ($i = 1, \ldots, m$) and $b_j$ be the capacity of the parking slot $p_j$. The set up cost and weight of the parking slot $p_j$ ($j = 1, \ldots, n$) be denoted by $c_j$ and $w_j$ respectively.

Let $\rho_j = \frac{c_j}{\sum_{j=1}^{n} c_j} (1 - w_j)$ denote the weighted cost of parking slot $p_j$. Here we take the weights $(1 - w_j)$ as our purpose is to minimize the weighted set up cost. The distance between the locality $l_i$ and parking slot $p_j$ is denoted by $d_{ij}$.

Then above described model is formulated as the following two objective non linear programming problem.

$$\min (C(x), D(x))$$

$$C(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} \rho_j x_{ij}$$

$$D(x) = \max\{d_{ij} : x_{ij} = 1 \ (i = 1, \ldots, m ; \ j = 1, \ldots, n)\}$$

($P$) subject to the constraints
\[ \sum_{j=1}^{n} x_{ij} = 1 \quad (i = 1, \ldots, m) \quad (2.1) \]

\[ \sum_{i=1}^{m} x_{ij} \leq \beta \quad 1 \leq \beta \leq m; \quad \beta \in N; \quad (j = 1, \ldots, n) \quad (2.2) \]

\[ \sum_{i=1}^{m} a_i x_{ij} \leq b_j \quad (j = 1, \ldots, n) \quad (2.3) \]

\[ x_{ij} = 0 \text{ or } 1 \quad (i = 1, \ldots, m; j = 1, \ldots, n) \quad (2.4) \]

It is to be noted that \( \beta = 1 \) if \( m \leq n \) whereas \( 1 < \beta \leq m \) for \( m > n \).

### 2.3 Solution Procedure

The above formulated problem is a bi-objective integer programming problem. The prioritized two-objective problem is reduced to an equivalent single-objective integer programming problem by using scalarization techniques. Surveys are conducted and corresponding positive reciprocal matrices are constructed at each level of hierarchy. MADM technique, AHP is used to calculate the weights for different criteria associated with a parking slot. The quandary is scalarized using MODM model ‘Weighted Penalty Method’ and subsequently solved using Hungarian Method to assignment problem and 0 – 1 integer programming.
Chapter 3

Site Selection Using Optimization Techniques

3.1 Introduction

This chapter extends the study conducted in chapter 2 by analyzing a three objective problem in relevance to site selection model. Almost all investment decisions involve multiple, diverse and complex set of social and financial factors which are quite hard to be overcome by mere intuition. A number of allocation problems have been solved in the recent past; see Ignizio(1982), Ignizio and Cavalier(1994). In Multi objective Programming Problems, there may not be a single solution that simultaneously optimizes each objective to its fullest. In each case an objective must have reached a point such that, while attempting to optimize it further, other objectives suffer as a result. Finding such a solution and quantifying how much better this solution is compared to many other such solutions, is the goal when setting up and solving a Multi-objective Optimization Problem; see Azarm(1994), Prakash and Gupta(2006), Serafini(1985) and Steuer(1986). Here we envision a site selection model for commercial activities which efficiently explores a multi-criteria
decision-making model involving three objectives. Maximization of profit and mini-
mization of set-up cost are the major objectives. Third objective is to rank various
attributes such as capacity, neighborhood, connectivity, transport availability and
proximity which are considerably important factors for a flourishing business.

3.2 Problem Description and Mathematical Form-
mulation

Suppose a corporate body/M.N.C. deals in \( m \) different business/outlets and there
are \( n \) available sites \( (m \leq n) \). Problem is to allocate a suitable site out of the
available sites to each business/outlet. While doing this, the two major objectives
of the company are to maximize the overall profit and to minimize the overall cost.
At the same time, the company wants to prioritize the sites carrying more weights
for flourishing business.

Let \( p_{ij} (i = 1, \ldots, m; j = 1, \ldots, n) \) denote the expected profit, when \( i^{th} \) business
is set up at \( j^{th} \) site. Also let \( c_j \) be the overall cost and \( w_j \) be the weight of \( j^{th} \) site
\((j = 1, \ldots, n)\) calculated using AHP. Let \( \rho_j \) denote the normalized cost of the \( j^{th} \) site.
Then \( (1 - \rho_j) = r_j \) denotes the reversed cost of the \( j^{th} \) site. It is to be noted
that we have reversed the cost as our objective is to minimize the cost and on the
contrary, we are dealing with a maximization problem. Then the above described
model is formulated as the following three objective problem.

\[
\text{(A) Maximize } Z(X) = (P(x), R(x), W(x)) \\

P(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij}x_{ij}, \quad R(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} r_{ij}x_{ij}, \quad W(x) = \sum_{i=1}^{m} \sum_{j=1}^{n} w_{ij}x_{ij}
\]
subject to the constraints:

\[ \sum_{j=1}^{n} x_{ij} = 1 \quad (i = 1, \ldots, m) \quad (3.1) \]
\[ \sum_{i=1}^{m} x_{ij} \leq 1 \quad (j = 1, \ldots, n) \quad (3.2) \]
\[ x_{ij} = 0 \text{ or } 1 \quad (i = 1, \ldots, m ; j = 1, \ldots, n) \quad (3.3) \]

### 3.3 Solution Procedure

The solution procedure consists of two phases. In the first phase, weights are allocated to various available sites based on various important aspects such as neighboring locality, broad or narrow connecting roads, area/capacity of the available sites, proximity factors such as competitive business rivals in the nearby areas, transport availability such as metro or other public transports. To accomplish this, an approach of Analytic Hierarchy Process (AHP) given by Saaty (1980) is used.

In the second phase, the three objective problem seeking to maximize the profit, minimize the set up cost born by the investors and to maximize qualitative standards is untangled using Lexicographic approach and thereafter solved using integer programming. A comparative solution is projected using scalarization method.
Chapter 4

Leader Culling Using AHP - PROMETHEE Methodology

4.1 Introduction

This chapter proposes the use of improved PROMETHEE methodology for candidate selection eligibility and has the potential to re-shape and influence the way the general public perceive social justice for a rational decision. PROMETHEE is a MCDM method well adapted to problems where a finite number of alternatives are to be ranked considering several, sometimes conflicting, criteria. It has successively been applied in many fields especially in the investment analysis and performance evaluation. Albadvi(2007), Babic and Plazibat(1998), Bouri(2000), Mareschal(1988), Mareschal and Brans(1988; 1991) and Vranegl(1996), all applied PROMETHEE as a decision making tool to solve the different problems in the field of finance.

The developed methodology facilitates the selection procedure in a rational and transparent way that can be examined and understood by the concerned voters. The objective quality of this method keeps inconsistency of decision makers’ op-
posing views within reasonable limits. The study is substantiated using Simple Additive Weighting (SAW) technique. The factors considered here explore personal as well as professional aspects of the aspiring candidates. The employed methodology utilizes systematic approach to screen and ultimately select the most suitable candidate.

4.2 Problem Description

A group of voters is asked to select a candidate among a set of contesting candidates. Each voter has a personal ranking of the candidates according to his/her preferences. The development of a ranking procedure requires a consensus on a set of criteria for evaluation, upon which the selection of candidates will be based. Potentially large number criteria are to be judged on a valid scale that is acceptable to all the participants. The most critical phase in designing the selection process model is to structure the decision problem. The main goal is to select the best candidate, according to a set of criteria for evaluation. As conflicting views may arise among different communities in determining the most important criteria of evaluation in a given decision making setting, a general survey was conducted to develop the main criteria, sub criteria and categories for each sub criteria for achieving the goal.

4.3 Solution Procedure

Various surveys were conducted to rate each attribute to others in a series of pairwise comparisons. An approach of AHP is applied to find out the weights of each criterion at different levels of hierarchy. The evaluation process finally generates the global weights for each requisite criterion of interest. After having weight allocations to the set of perceived criteria via AHP, the problem of selection of suitable candidate is submitted to PROMETHEE II methodology for a pertinent ranking.
Chapter 5

Agronomic Business Promotion

5.1 Introduction

Present chapter critically analyzes the agronomic market opportunities for the investors so as to formulate better merchandise programs. Rural markets in India constitute a wide and untapped market for many products and services which are being marketed for the urban masses. The urban market reaching almost to a saturation level, demand from rural India has been on a high trajectory. It provides a promising business as many new products have already made their entry into the rural consumer basket. Thus, Indian rural markets have caught the attention of many companies, advertisers and multinational companies. Contemporary desideratum is what kind of investments is required to unlock long-term value from rural markets.

5.2 Problem Statement

A marketer trying to market his product or service in the rural areas is faced by many challenges; the first is posed by the geographic aspects like location, profit cost revenue, population density and climatic conditions. The second challenge is from
the demographic factors like purchasing power, literacy level and denominations in the region. Third is psychographic segmentation like activities, interests and ethics of the residents. And last but not the least are behavioristic influences namely usage rates, brand loyalty and festivity. One of the key issues, which require research, is the methodology by which we can design a cost effective, efficient, environment friendly model which is befitting on the above set of criteria.

5.3 Solution Procedure

To evaluate the hierarchy, decision makers are asked to allot rankings to the leveled criteria according to their requisite priorities. Numeric weights are provided to all the criteria using MAGIQ technique. TOPSIS has been used to provide final rankings to available agronomic locations. Various surveys were conducted to rate each attribute to others in a series of pair wise comparisons. An approach of AHP is applied to find out the weights of each criterion at different levels of hierarchy. The evaluation process finally generates the global weights for each requisite criterion of interest. After having weight allocations to the set of perceived criteria via AHP, the problem of selection of suitable candidate is submitted to PROMETHEE II methodology for a pertinent ranking.
Chapter 6

A Qualitative Assessment of Educational Software

6.1 Introduction

This chapter inspects the prerequisite of children’s software evaluation in the light of dynamic nature of edutainment perspective. The work provides comparative ranking of educational software for scholastic programs scouting both technical and non technical aspects. Work was conducted to help educational institutions gain a deeper understanding of professional decisions they face and reduce their initial state of uncertainty about the best course of action. The Internet-related technologies have helped to lay the blueprint for the futuristic software evaluation information in the 21st century. More studies need to be accomplished in this field, as that done by Escobedo and Evans(1997), where the ratings assigned by the published software methods are compared with actual child selection or Tammen and Brock(1997), where middle school students are asked to identify issues they feel are important for the evaluation of software programs.
6.2 Problem Statement

The problem of evaluation of alternatives submitted to a multi-criteria decision analysis is a contentious task. Usually there is no optimal solution as no alternative is the best one on each criterion. Problem is to evaluate the software according to their credibility on the set of weighted judgment criteria. The most demanding phase in designing the evaluation model is to structure the decision problem. The goal is to reckon the software according to a set of criteria for evaluation. The conventional approach to predictive evaluation is to use a checklist exploring technical and non-technical features of the requisite software.

6.3 Solution Procedure

Rank Order Centroid (ROC) methodology and Ratio Method are used to accomplish the result. The key advantage of ROC Methodology is its simplicity in surveying whereas Ratio method requires quantified rating of prioritized alternatives. Ratio Method has its own advantages when the decision makers influence their prioritized specifications regarding significances.
Chapter 7

Improving Consistency of Comparison Matrices in Analytical Hierarchy Process

7.1 Introduction

This chapter designs a contemporary MADM model to assist the decision making scenarios and is specifically applicable to multi-criteria decision problems associated with large number of attributes. Antecedent of inconsistencies are analyzed and a corrective application based approach is introduced to construct nearly consistent matrices. The analysis extends the previous researches in many ways. Firstly, it analyzes the root causes of inconsistencies in pairwise comparison matrices and suggests the constructive approaches to overcome the discrepancies. Secondly, the model enables us to visualize the impact of various criteria on the final ranking and determine the level of importance of each criterion based on survey analysis. Thirdly, implementing above methodology can serve as a paradigm for MCDM problems for which similar models can be developed, modified and improved. A
further advantage concerns this model’s inherent ability to procure instant reporting of analysis results, where numerous subtle factors are involved.

7.2 Research Methodology

Decision Makers are more likely to be cardinally inconsistent because they cannot estimate precise measurement values even from a known scale and worse when they deal with intangibles (a is preferred to b twice and b to c three times, but a is preferred to c only five times). Here the first reason of inconsistency appears. This is referred to as inconsistency of reciprocity. Again, judgments are ordinally intransitive if (\( A \) is preferred to \( B \) and \( B \) to \( C \) but \( C \) is preferred to \( A \)). One of the apparent reason is, large number of pairwise comparisons \( \binom{n}{2} \) required to workout the attribute weights at a given level of hierarchy. This results in baffling responses relating to pairwise comparisons. This is termed as inconsistency of transitivity and it goes on increasing with the size of the matrix.
Chapter 8

Conclusion of the Thesis

In this work, an integrated solution methodology for a general discrete Multi Criteria Decision Making (MCDM) problem is developed based on various interactive approaches. The concept is designed to make better choices when faced with complex decisions involving several dimensions. MCDM tactics are especially helpful when there is a need to combine hard data with subjective preferences, to make trade-offs between desired outcomes and to involve multiple decision makers. In the decision making process, there are typically multiple conflicting criteria that need to be assessed simultaneously with about same degree of precedence. This craves the search for an approach which deals the predicament with necessary sagacity to obtain a clear and unambiguous conclusion. In this chapter, we summarize the work done in this dissertation in the said field and draw conclusions of this R and D. We also discuss limitations of this investigation and suggested implications. Future plan of action for further research is also acknowledged.

8.1 Summary of the Content and Conclusions

Chapter 1 is introductory and covers literature review and introduction to Multi Criteria Decision Making (MCDM) methodologies.
Chapter 2 propounds a multi-criteria decision-making assignment model to allocate appropriate parking slots to various localities. The proposed methodology provides a decision making method for development of parking slots to decision maker who is interested in minimizing the total cost as well as the distance traversed by the residents. Sets of efficient solutions for allotting parking slots seeking minimization of cost as the first priority objective and minimization of distance as the second priority objective has been obtained. Concepts of assignment model and integer programming have been used to assign parking slots to various localities. Heuristics have effectively helped in getting precise and practicable solution. The study suggests sharing of parking slots if number of localities exceeds the available number of parking slots.

Chapter 3 augments the study conducted in chapter 2 by analyzing a three objective problem in relevance to site selection model. While strategically managing our location decisions, we need solutions that address multiple logistics and economic factors involving real estate and our customers. Maximization of profit and minimization of set-up cost are the two major objectives. Third objective is to rank the sites qualitatively, for a flourishing business. MADM model, AHP has been used to rank various relating attributes. A comparative study is conducted using MODM models ‘Weighted Penalty Method’ and ‘Lexicographic Approach’. The method also suggested that once starting up with a low profit/low cost model, high futuristic growth may be expected if qualitative ranks are high.

Chapter 4 proposes to combine two MADM tactics for efficient manipulation of candidate selection procedure. An approach of AHP is applied to find out the weights of each criterion at different levels of hierarchy. After having weight allocations to the set of perceived criteria via AHP, the problem of selection of suitable candidate is submitted to PROMETHEE II methodology for a pertinent ranking. The present study reveals that above methodology can be utilized as a valuable
decision-making process to evaluate the contestants in a logical and consistent fashion for many reasons.

Chapter 5 critically analyzes the agronomic market opportunities for the investors so as to formulate better merchandise programs. Here also two MADM methodologies are merged, intending to simplify the ranking procedure, taking into account illiteracy problem in rural areas. Numeric weights are provided to all the criteria using MADM technique, Multi Attribute Global Inference of Quality (MAGIQ). Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) has been used to provide final rankings to available agronomic locations. There is a promising business and definitely a lot of money in rural India but the smart thing would be to weigh crucial attributes strategically for tactical gains.

Chapter 6 inspects the prerequisite of childrens software evaluation in the light of dynamic nature of edutainment perspective. Work was conducted to help educational institutions gain a deeper understanding of professional decisions they face and reduce their initial state of uncertainty about the best course of action. Comparative solutions are provided using two MADM techniques Rank Order Centroid (ROC) methodology and Ratio Method.

Chapter 7 designs a novel MADM model to assist the decision making scenarios and is specifically applicable to multi-criteria decision problems associated with large number of attributes. We have described the implementation of a corrective model, assisting the decision-maker in the construction of a consistent comparison matrix. Group decision making is becoming increasingly important in decision scenarios associated with MCDM problems. The proposed methodology provides an insight into the impediments to effective group processes and on techniques that can improve group decisions. We hope that the projected approach can refocus the attention of researchers from the race of finding better judgments for inconsistent and near consistent matrices.
8.2 Summarizing the Findings and Limitations

This study has shown that methodologies adapted from MCDM tactics have versatile applications in almost all decision making layouts. Application feasibility as well as efficiency of the tactics in solving diversified problems have been described illustratively in this study. Expert opinions are sought and implemented to scout empirical perfections. Some limitations to this pilot study need to be acknowledged.

One of the more significant findings that emerge from this study is that, AHP is a useful decision tool to consolidate evaluation data. It provides a useful mechanism for checking the consistency of the evaluation measures and alternatives. This method is preferred over other established methodologies as it does not demand prior knowledge of the utility function; rather it is based on a hierarchy of criteria and attributes facilitating the understanding of the problem. It allows relative and absolute comparisons, making this method a very robust tool. This method allows combinations with other techniques as well as scenario analysis and simulation exercises. The further strength of the AHP is its ability to detect inconsistent judgments. Last but not the least, AHP allows group decision-making and is convenient in numerical handling. Free on line software support is an added advantage.

The limitation of the AHP is that, it only works for positive reciprocal matrices. The other seeming drawback is the scale used in judgment mechanism which inculcates inconsistencies in assessments. Large number of pairwise comparisons required for sizable comparison matrices is another snag which seeks research for further improvement.

It was also shown that MAGIQ technique using rank order centroids for weight determination is another useful MADM model. It is far more quicker to other analogous techniques used for the decision mechanism. The key advantage of the methodology is its simplicity in surveying, yet it has its own limitations when the
decision makers influence their prioritized specifications regarding significances. This study also found that PROMETHEE and TOPSIS used in the present work are simple and logical MADM tactics widely used in decision scenarios. Still they have their own limitations in practical implications. Major of them is, the requirement of predefined criteria weights which seeks the help of other MADM procedures. Further complication in PROMETHEE is requirement of preference functions as proposed in original inception. But these preference functions require the definition of some preferential parameters, such as the preference and indifference thresholds. However, in real time applications, it may be difficult for the decision maker to specify which specific form of preference function is suitable for each criterion and also to determine the parameters involved. Another apparent constraint is, limited software support which enhances manual computations.

Another important findings regarding the two MODM techniques used in this work indicate that Lexicographic Approach is useful only when objectives considered in the study are few. Also it does not provide alternatives to the aspirants for individual preferences whereas Weighted Penalty Method provides a set of efficient solutions which can be evaluated for prioritized preferences. However it was observed that weights allotted for scalarization purpose in Weighted Penalty Method in the present work may significantly effect the decision layouts.

8.3 Suggested Implications (Research Contribution)

The present study confirms previous findings and contributes additional evidences that suggest that pairwise comparison methods can always be used to draw the final conclusions in a comparatively accessible and intelligible way. However, as the results suggest that AHP should be used in combination with other decision tools to
support because AHP is efficient only when the number of criteria and alternatives are few.

The methodology of PROMETHEE and its algorithm has been demonstrated in detailed and simplified way and it is believed that it will be useful for decision makers to apply such MCDM tools to supplement their decision-making efforts. A contemporary decision making technique has been brought up in this work in which antecedent of inconsistencies are analyzed and a corrective application based approach is introduced, which helps the decision-maker to build consistent matrices with controlled error by appreciably less number of pairwise comparisons.

8.4 Recommendations for Further Work (Research)

The current findings add substantially to our understanding of incorporating MCDA tactics in decision layouts. The empirical findings in this study will serve as a base for future studies in various application scenarios.
References


[38] Ishizaka, A. & Lusti, M. (2004). An expert module to improve the consistency of


Bibliography


