AHP MODEL FOR OPTIMUM DISTRIBUTION NETWORK SELECTION IN FOOD INDUSTRY

NAFISEH GHORBANI RENANI

A project report submitted in partial fulfilment of the requirements for the award of the degree of Master of Engineering (Industrial Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2013
ACKNOWLEDGEMENT

First and Foremost, I would like to express my sincere gratitude to my supervisor Prof. Dr. Syed Ahmad Helmi Syed Hassan for the continuous support of my study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

Besides my supervisor, I would like to thank to the staffs of Malaysian Ketchup sauce manufacturers for their kind cooperation and support.

I would like to express my sincere appreciation to my mother and father, who have always supported me emotionally, I would also thank to AMIR and IMAN, my beloved brothers, who have helped me and encouraged me for higher education.

Especial thanks goes to my wonderful husband, ALIREZA, for his enduring love and for sharing my wish to reach the goal of completing this task.

Lastly, I would like to thank to my numerous friends and all people who have helped me during conducting my master project.
ABSTRACT

Efficient supply chain distribution network design must take into account various dimensions of performance and product characteristics. The appropriate choice of distribution network results in customer needs being satisfied at the lowest possible cost. Investigators have recently begun to realize that the decision in the supply chain distribution network design must be driven by an extensive set of performance metrics and the characteristics of the products. In this thesis, cost and service factor performance metrics were regarded as the decision criteria for optimizing supply chain distribution network design. Qualitative and quantitative factors were considered in selecting the optimum delivery network design by using Analytic Hierarchy Process (AHP) methodology. After aggregating the ideas of a group of experts and customers, the selection decision is made. Sensitivity analysis was performed to show the robustness and consistency of the model. The results of the analysis illustrate the model is found to be stable and robust and the ketchup sauce manufacturers can select their suitable and optimum distribution network designs according to this study.
ABSTRAK

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td></td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td></td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td></td>
<td>xvii</td>
</tr>
</tbody>
</table>

## 1 INTRODUCTION

1.1 Introduction 1
1.2 Research Background and Motivation 2
1.3 Problem Statement 3
1.4 Objective of the Study 4
1.5 Scope of the Study 5
1.6 Significant of the Study 5
1.7 Organization of Thesis 6
1.8 Conclusion 6

## 2 LITERATURE REVIEW 7
2.1 Introduction 7
2.2 The Role of Distribution in Supply Chain 7
2.3 Factors Influencing Distribution Network Design 9
2.4 Design Options for a Distribution Network 10
2.4.1 Manufacturer Storage with Direct Shipping 11
2.4.2 Manufacturer Storage with Direct Shipping and In-transit Merge 12
2.4.3 Distributor Storage with Package Carrier Delivery 13
2.4.4 Distributor Storage with Last Mile Delivery 14
2.4.5 Manufacturer / Distributor Storage with Customer Pickup 15
2.4.6 Retail Storage with Customer Pickup 16
2.5 Selecting a Distribution Network Design 17
2.5.1 Delivery Network Design Comparison Based on Performance Metrics 19
2.5.2 Delivery Network Design Comparison Based on Product Characteristics 20
2.6 Analytic Hierarchy Process (AHP) 21
2.6.1 AHP Procedure 22
2.7 Conclusion 30

3  RESEARCH METHODOLOGY 31
3.1 Introduction 31
3.2 Research Framework 31
3.3 Questionnaire Design 35
3.3.1 Definition of Terms 35
3.4 Sample Selection 36
3.5 Research Equipment 37
3.6 Conclusion 37

4  DATA COLLECTION AND ANALYSIS 38
4.1 Introduction 38
4.2 Data Collection Description 38
4.3 Result of the Data Collection 39
  4.3.1 Part I of Data Gathering 40
  4.3.2 Part II of Data Gathering 46
  4.3.3 Part III of Data Gathering 49
  4.3.4 Part IV of Data Gathering 52

4.4 Conclusion 54

5 RESULTS DISCUSSION AND CONCLUSION 56
  5.1 Introduction 56
  5.2 Results of the Study 56
    5.2.1 Ranking of Cost and Service Factors Criteria 57
    5.2.2 Ranking of Alternatives with Respect to Cost Factors Criteria 58
    5.2.3 Ranking of Alternatives with Respect to Service Factors Criteria 61
    5.2.4 The Overall Ranking of Alternatives with Respect to the Goal 64
  5.3 Sensitivity Analysis 65
    5.3.1 Head-to-Head Graph 65
    5.3.2 Two Dimensional Graph 69
    5.3.3 Performance Sensitivity 71
  5.4 Recommendations for Future Research 77
  5.5 Significant of Findings 78
  5.6 Conclusion 79

REFERENCES 81

Appendices A - B 83 - 89
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Performance Type for Defining Criteria and Sub-criteria Type</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Summary of the Characteristics of the Distribution Network (Mithun, 2008)</td>
<td>18</td>
</tr>
<tr>
<td>2.3</td>
<td>Comparative Performance of Delivery Network Designs (Chopra and Meindl, 2010)</td>
<td>19</td>
</tr>
<tr>
<td>2.4</td>
<td>Performance of Delivery Networks for Different Product or Customer Characteristics (Chopra and Meindl, 2010)</td>
<td>21</td>
</tr>
<tr>
<td>2.5</td>
<td>Preference Scale for Pair-wise Comparisons (Saaty, 1977)</td>
<td>24</td>
</tr>
<tr>
<td>2.6</td>
<td>Pair-wise Comparison Matrix for Customer Market (Taylor, 2010)</td>
<td>24</td>
</tr>
<tr>
<td>2.7</td>
<td>Normalized Matrix for Customer Market (Taylor, 2010)</td>
<td>25</td>
</tr>
<tr>
<td>2.8</td>
<td>The Normalized Matrix with Row Averages (Taylor, 2010)</td>
<td>25</td>
</tr>
<tr>
<td>2.9</td>
<td>Criteria Preference Matrix (Taylor, 2010)</td>
<td>26</td>
</tr>
<tr>
<td>2.10</td>
<td>Pair-wise Comparison for the Four Criteria (Taylor, 2010)</td>
<td>26</td>
</tr>
<tr>
<td>2.11</td>
<td>Normalized Matrix for Criteria with Row Averages (Taylor, 2010)</td>
<td>27</td>
</tr>
<tr>
<td>2.12</td>
<td>RI Values for n Items Being Compared (Taylor, 2010)</td>
<td>29</td>
</tr>
<tr>
<td>4.1</td>
<td>Cronbach’s alpha Reliability Test (Kline, 1999 and George and Mallery, 2003)</td>
<td>40</td>
</tr>
</tbody>
</table>
4.2 Criteria Weighting Matrix
4.3 Example of Calculation of Final Score for Response Time
4.4 Final Scores of Customer Service Factors
4.5 Definition of Criteria and Sub-criteria
4.6 Pair-wise Comparison of Alternatives for $C_{c1}$
4.7 Pair-wise Comparison of Alternatives for $C_{c2}$
4.8 Pair-wise Comparison of Alternatives for $C_{c3}$
4.9 Pair-wise Comparison of Alternatives for $C_{c4}$
4.10 Pair-wise Comparison of Alternatives for $C_{s1}$
4.11 Pair-wise Comparison of Alternatives for $C_{s2}$
4.12 Pair-wise Comparison of Alternatives for $C_{s3}$
4.13 Pair-wise Comparison of Alternatives for $C_{s4}$
4.14 Comparison of Service Factors Sub-criteria (group A)
4.15 Comparison of Service Factors Sub-criteria (group B)
4.16 Comparison of Service Factors Sub-criteria (group C)
4.17 Aggregation of Preferences of Customers
4.18 Comparison of Cost Factors Sub-criteria (factory A)
4.19 Comparison of Cost Factors Sub-criteria (factory B)
4.20 Comparison of Cost Factors Sub-criteria (factory C)
4.21 Comparison of Cost Factors Sub-criteria (factory D)
4.22 Aggregation of Preferences of Manufacturers’ Experts
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Manufacturer Storage with Direct Shipping</td>
<td>12</td>
</tr>
<tr>
<td>2.2</td>
<td>Manufacturer Storage with Direct Shipping and In-transit Merge</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>Distributor Storage with Package Carrier Delivery</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Distributor Storage with Last Mile Delivery</td>
<td>15</td>
</tr>
<tr>
<td>2.5</td>
<td>Manufacturer / Distributor Storage with Costumer Pickup</td>
<td>16</td>
</tr>
<tr>
<td>2.6</td>
<td>Retail Storage with Customer Pickup</td>
<td>17</td>
</tr>
<tr>
<td>3.1</td>
<td>Research Framework</td>
<td>34</td>
</tr>
<tr>
<td>4.1</td>
<td>Pareto Chart</td>
<td>45</td>
</tr>
<tr>
<td>4.2</td>
<td>Proposed AHP Model for the Problem</td>
<td>46</td>
</tr>
<tr>
<td>5.1</td>
<td>Ranking of the Cost Factor Criteria</td>
<td>57</td>
</tr>
<tr>
<td>5.2</td>
<td>Ranking of the Service Factor Criteria</td>
<td>58</td>
</tr>
<tr>
<td>5.3</td>
<td>Ranking of Alternatives for Inventory</td>
<td>59</td>
</tr>
<tr>
<td>5.4</td>
<td>Ranking of Alternatives for Transportation</td>
<td>59</td>
</tr>
<tr>
<td>5.5</td>
<td>Ranking of Alternatives for Facilities and Handling</td>
<td>60</td>
</tr>
<tr>
<td>5.6</td>
<td>Ranking of Alternatives for Information</td>
<td>60</td>
</tr>
<tr>
<td>5.7</td>
<td>Overall Ranking of Alternatives with Respect to Cost Factors</td>
<td>61</td>
</tr>
</tbody>
</table>
5.8 Ranking of Alternatives for Response Time 61
5.9 Ranking of Alternatives for Product Availability 62
5.10 Ranking of Alternatives for Customer Experience 62
5.11 Ranking of Alternatives for Returnability 63
5.12 Overall Ranking of Alternatives with Respect to Service Factors 63
5.13 Overall Ranking of Alternatives with Respect to Goal 64
5.14 Head-to-Head Graph between Alternative 4 and 1 under Cost Factors Criteria 66
5.15 Head-to-Head Graph between Alternative 4 and 2 under Cost Factors Criteria 67
5.16 Head-to-Head Graph between Alternative 4 and 3 under Cost Factors Criteria 67
5.17 Head-to-Head Graph between Alternative 4 and 1 under Service Factors Criteria 68
5.18 Head-to-Head Graph between Alternative 4 and 2 under Service Factors Criteria 68
5.19 Head-to-Head Graph between Alternative 4 and 3 under Service Factors Criteria 69
5.20 Two-Dimensional Graph for Response Time and Returnability 70
5.21 Two-Dimensional Graph for Transportation and Inventory 70
5.22 Performance Sensitivity Graph for Cost Factors Criteria 71
5.23 Performance Sensitivity for Information by Increasing the Value 72
5.24 Performance Sensitivity for Information by Decreasing the Value 73
5.25 Gradient Graph for Information 73
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.26</td>
<td>Performance Sensitivity Graph for Service Factors Criteria</td>
<td>74</td>
</tr>
<tr>
<td>5.27</td>
<td>Performance Sensitivity for Product Availability by Increasing the Value</td>
<td>74</td>
</tr>
<tr>
<td>5.28</td>
<td>Performance Sensitivity for Product Availability by Decreasing the Value</td>
<td>75</td>
</tr>
<tr>
<td>5.29</td>
<td>Gradient Graph for Product Availability</td>
<td>76</td>
</tr>
<tr>
<td>5.30</td>
<td>Performance Sensitivity Graph for Cost and Service Factors Criteria</td>
<td>77</td>
</tr>
<tr>
<td>5.31</td>
<td>Performance Sensitivity Graph for Cost and Service Factors by Increasing the Value of Service Factor</td>
<td>77</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
</tr>
<tr>
<td>CR</td>
<td>Consistency Ratio</td>
</tr>
<tr>
<td>CI</td>
<td>Consistency Index</td>
</tr>
<tr>
<td>DC</td>
<td>Distribution Centre</td>
</tr>
<tr>
<td>MCDM</td>
<td>Multi Criteria Decision Making</td>
</tr>
<tr>
<td>RI</td>
<td>Random Index</td>
</tr>
<tr>
<td>SGMM</td>
<td>Simple Geometric Mean Method</td>
</tr>
<tr>
<td>UTM</td>
<td>Universiti Teknologi Malaysia</td>
</tr>
<tr>
<td>WGMM</td>
<td>Weighted Geometric Mean Method</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

\( \lambda_i \) - Weight of each decision maker in WGM Method

\( X \) - The set containing the ideas of decision makers

\( X_i \) - Idea of each decision maker in WGM Method

\( C_{ci} \) - Cost factor criteria

\( C_{si} \) - Service factor criteria

\( A_i \) - Alternatives of distribution network design

\( C \) - Cost factor

\( S \) - Service factor
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Questionnaire</td>
<td>83</td>
</tr>
<tr>
<td>B</td>
<td>Reliability test results of questionnaire</td>
<td>89</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

Supply chain is a network of facilities, such as suppliers, plants, distributors, warehouses, retailers which performs a set of operations including procurement of components and raw materials, assembling of products, storage and handling of semi finished and finished products, transportation and delivery of products, and so on (Ding et al., 2007).

Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it directly affects both the supply chain cost and the customer experience. Choice of distribution network can achieve supply chain objectives from low cost to high responsiveness. As a result, companies in the same industry often select very different distribution networks (Chopra and Meindl, 2010).

Dell distributes its PCs directly to end consumers, while companies like Hewlett Packard and Compaq distribute through resellers (Magretta, 1998). Dell customers wait several days to get a PC while customers can walk away with an HP or Compaq PC from a reseller. Gateway opened Gateway Country stores where
customers could check out the products and have sales people help them configure a PC that suited their needs. Gateway, however, chose to sell no products at the stores, with all PCs shipped directly from the factory to the customer. In 2001, Gateway closed several of these stores given their poor financial performance. Apple Computers is planning to open retail stores where computers will be sold (Wong, 2001). These PC companies have chosen three different distribution models. How can we evaluate this wide range of distribution choices? Which ones serve the companies and their customers better? This research is more focused on selecting an appropriate distribution network for a specific company which provides customer satisfaction at the lowest cost.

This chapter explains background of the study, problem statement, objectives, scope, significance of the study, the research outline following by conclusion.

1.2 Research Background and Motivation

Effective supply chain distribution network design needs to consider various performance dimensions and product characteristics. It is clearly important to design or redesign a production distribution network based on a comprehensive optimization analysis.

The results obtained by academic researchers have been partially put into practice. Recently, researchers have begun to realize that the decision and integration effort in supply chain design should be driven by a comprehensive set of performance metrics and also product characteristics (Mithun, 2008).

Despite attempts to choose the best delivery network design or combination of design, it is still a major challenge for the decision maker. There is still need to investigate the design/selection of an appropriate supply chain distribution network
design to achieve optimal performance, which is measured using a set of metrics and criteria. Most decision makers make qualitative analysis to design the distribution network. Through their experience and intuition they select a combination of these network designs. But there is no research so far in optimizing the designs objectively so as to make feasible decisions whether it is a single or combination of selections.

Therefore, this research provides a framework and identifying key dimensions along which to evaluate the performance of any distribution network. To achieve this goal it is proposed to use multi-criteria decision-making tool known as analytical hierarchy process (AHP).

1.3 Problem Statement

Production distribution network design is a critical decision that has significant impacts on a supply chain’s long-term performances. One of the most important problems in supply chain management is the distribution network design problem system which involves locating production plants and distribution warehouses, and determining the best strategy for distributing the product from the plants to the warehouses and from the warehouses to the customers (Golmohammadi et al., 2009).

Herein, it is considered that the problem of designing a distribution network that involves determining the best strategy for distributing the product from the plants to the warehouses and from the warehouses to the customers.

Hence choosing the best delivery network design or a combination of design is a major challenge for the decision maker. Firms can make many different choices when designing their distribution network. A poor distribution network can hurt the level of service that customers receive while increasing the cost. An inappropriate
network can have significant negative effect on the profitability of the firm. The appropriate choice of distribution network results in customer needs being satisfied at the lowest possible cost (Mithun, 2008).

Therefore, design of distribution network in supply chain needs to focus primarily on the objectives and not just the development of tools used in decision making. This study primarily deals with the design/selection of an appropriate supply chain configuration to achieve optimal performance, which is measured using a set of metrics. Thus, four companies of a consumer product located in Johor, Malaysia are selected for this survey. The best distribution network was selected, results in customer needs being satisfied at the lowest possible cost.

1.4 Objective of the Study

The study aims to select suitable distribution network design based on performance metrics for companies of a consumer product located in Malaysia.

Specific objective associated with this aim is designing a distribution network that the demands of all customers are satisfied with the minimum of transportation and warehousing cost.

1.5 Scope of the Study

This study primarily focuses on identifying appropriate distribution network designs in four ketchup sauce manufacturers who are from the same type of
industries and produce the same product in Malaysia. The scope of this study is determining the suitable distribution network design for this kind of industry.

AHP methodology will be applied which will select the best set of multiple distribution networks to satisfy profitability and customer satisfaction.

1.6 **Significant of the Study**

As at now, there is no known study in optimizing the designs of distribution network objectively so as to make feasible decisions whether it is a single or combination of selections in Johor. This study attempted to provide more information in optimizing supply chain delivery network design and adopt cost and service factor performance metrics as the decision criteria.

The study could be served as a guide to select the appropriate choice of distribution network from the manufacturer to the end consumer results in customer needs being satisfied at the lowest possible cost and as a reference material to decision makers and future scholars in this area. This is done by presenting better understanding of performance metrics influencing distribution network design which are cost and service factor. Then, it will provide managers with logical framework for selecting the appropriate distribution network given product, competitive and market characteristics. Also the proposed procedure enables managers of similar firms and industries to adjust a combination of network design to eliminate risk and to enhance service quality and profitability.
1.7 Organization of Thesis

This thesis is organized into five chapters. Chapter one introduces the study background and motivation, statement of the research problem, research objectives, research scope and significant of study.

Chapter two reviews relevant research studies on understanding the role of distribution within supply chain and identifies factors that should be considered when designing a distribution network.

Chapter three provides the methodology of the study so that it can be carried out systematically. The major sections of this chapter are research framework and model, questionnaire and choice of optimizing technique.

In chapter four, different parts of data gathering will be described and the results obtained from these parts of data collection are presented.

In the last chapter, the results of the work are provided to show the outcomes of questionnaire and AHP method to the problem. In addition, a brief discussion about the results is presented to give a better understanding. Finally, some recommendations are offered for the future studies that can be done in the area.

1.8 Conclusion

This chapter has described about the introduction to this project. All details about the problems, objective, scope, and significant of the study has been explained. The next chapter, Chapter 2, will present a literature review related to the research.
REFERENCES


Ferretti, I., Zanoni, S., Zavanella, L., (2006), Distribution network design under uncertain demand, Dept of Mechanical and Industrial Engineering, Università degli Studi di Brescia.


