UNIVERSITI PUTRA MALAYSIA

INTEGRATION OF AN IMPROVED GREY-BASED METHOD AND FUZZY MULTI-OBJECTIVE MODEL FOR SUPPLIER SELECTION AND ORDER ALLOCATION

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By

OMID JADIDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

April 2009

DEDICATION

To

My Parents and Wife

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Tang Sai Hong, PhD

Faculty : Engineering

For multi-attribute decision making (MADM) problems, a grey based approach (LI) had been developed to evaluate, rank and select the best suppliers. The method calculates a grey possibility degree between compared suppliers alternatives set and positive ideal referential alternative. The drawback of the method is that the negative ideal referential alternative is not considered in evaluating and ranking of the alternatives. Moreover, the method can only consider interval fuzzy number as input data and real number is neglected. Based on this model and other MADM methods, all demand was sold by the best supplier. In other cases, if the best supplier cannot satisfy all demand, multi-objective programming is used to formulate the problem and assign optimum order quantities to the best suppliers (multi-sourcing). Some techniques, such as goal programming (GP) approach, ε-Constraint method, Reservation level (RL) driven Tchebycheff procedure (RLTP) method had been proposed to solve the multi-objective models. It may be a problem that these

techniques traced back to more than 10 years ago. Therefore, there may be still the need to produce a new technique in order to solve the multi-objective models.

In this study, to overcome the first drawback, the LI method was improved based on the concepts of technique for order preference by similarity to ideal solution (TOPSIS) to consider both the positive and the negative ideal referential alternative for evaluation of the suppliers. The improved version of the LI method is called the I.LI method. Based on the concepts of TOPSIS, the chosen alternative should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution. Moreover, in order to solve the problems, a new grey based method (NG) based on the TOPSIS concepts was proposed that can easily consider both interval fuzzy number and real number simultaneously. Afterwards, an innovative comparative approach was proposed to compare the three MADM methods, the LI, the I.LI and the NG methods, and to show that which method is more optimal than the other methods.

Subsequently, in this thesis, an integration of the NG method and fuzzy multi-objective model was suggested for multi-sourcing and multi-product supplier selection problem. The score of suppliers calculated by the NG method was served as coefficients in one objective function of the multi-objective model. In this fuzzy multi-objective model, the products are divided into two independent and dependent products so that (1) the price breaks (discounts) depend on the size of the order quantities, (2) independent products' sales volume affect the prices and discounts of the dependent products and (3) all products must be sold as a bundle. Finally, to overcome the third problem, a new weighted additive function, which is able to consider relative importance of each objective as well as condition of fuzzy situation, is proposed to solve the fuzzy multi-objective model and assign optimum order quantities to the suppliers evaluated and ranked by the NG method.

The results of the innovative comparative approach showed that the result of the NG method is more optimal than the I.LI method and the latter is more optimal than the LI method. Therefore, the NG method was selected to be integrated with the fuzzy multi-objective model. Also, the fuzzy multi-objective model was solved by the new weighted additive function, and the results demonstrated that besides considering the relative importance of the objectives, the new technique is also able to consider the condition of fuzzy situation.

Abstrak tesis yang dikemukakan kepada Senat bagi Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

INTEGRASI PENAMBAHBAIKAN KAEDAH *GREY-BASED* DAN MODEL *FUZZY MULTI-OBJECTIVE* UNTUK PEMILIHAN PEMBEKALAN DAN PENENTUAN PEMESANAN

oleh

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Satu pendekatan *grey based* (LI) telah dibangunkan bagi menilai, menyusun dan memilih pembekal-pembekal terbaik untuk multi-atribut masalah penentuan keputusan (MADM). Kaedah ini mengukur darjah kebarangkalian (*grey possibility degree*) antara perbandingan set pembekal alternatif dengan pembekal rujukan alternatif yang ideal. Kelemahan kaedah ini adalah alternatif rujukan ideal yang negatif tidak diambil kira dalam penilaian dan penentuan alternatif. Kaedah ini hanya boleh menimbang jarak nombor *fuzzy* sebagai data input dan nombor nyata diabaikan. Berdasarkan model dan kaedah-kaedah MADM yang lain, semua permintaan telah dijual oleh pembekal terbaik. Dalam kes-kes lain, jika pembekal terbaik itu tidak boleh memuaskan semua permintaan, multi objektif pengaturcaraan akan digunakan untuk merumuskan masalah dan menentukan kuantiti pesanan optimum untuk pembekal-pembekal terbaik (multi sumber). Beberapa teknik seperti pendekatan pengaturcaraan matlamat (GP), kaedah *ε-Constraint*, tahap penempahan (RL) kaedah prosedur pacuan *Tchebycheff* (RLTP) dan sebagainya telah dicadangkan untuk menangani model-model multi objektif. Ia mungkin satu masalah yang mana

teknik-teknik ini dikesan kembali lebih daripada 10 tahun lalu. Oleh itu, mungkin ada keperluan untuk menghasilkan teknik terbaru dengan tujuan menyelesaikan model-model multi objektif.

Dalam kajian ini, untuk mengatasi kelemahan yang pertama, kaedah LI telah diperbaiki berdasarkan konsep bagi teknik untuk susunan keutamaan oleh persamaan untuk penyelesaian yang ideal (TOPSIS) dengan mempertimbangkan kedua-dua positif dan negatif rujukan alternatif yang ideal bagi penilaian ke atas pembekal. Kaedah LI yang telah diperbaiki dipanggil kaedah I.LI. Berdasarkan konsep TOPSIS, pilihan alternatif sepatutnya mempunyai jarak terdekat bagi penyelesaian ideal yang positif dan jarak terjauh bagi penyelesaian ideal yang negatif. Dengan tujuan menyelesaikan masalah 1 dan 2, satu kaedah baru *grey based* (NG) berdasarkan konsep TOPSIS telah dicadangkan yang membolehkan pertimbangan dibuat ke atas kedua-dua nombor perantaraan *fuzzy* dengan nombor sebenar secara serentak. Satu pendekatan perbandingan yang berinovasi telah dicadangkan untuk membandingkan tiga kaedah MADM, iaitu LI, I.LI dan kaedah NG dan bagi menunjukkan kaedah yang mana merupakan lebih optimum daripada kaedah yang lain.

Dalam tesis ini, satu pengintegrasian kaedah NG dan model *fuzzy multi-objective* telah diusulkan bagi penyelesaian masalah pemilihan pembekal *multi-sourcing* dan *multi-product*. Mata bagi pembekal dihitung oleh kaedah NG dalam satu fungsi objektif model multi-objektif. Dalam model *fuzzy* multi-objektif, produk-produk akan dibahagikan kepada dua iaitu produk independen dan produk dependen supaya (1) pecahan harga (diskaun-diskaun) bergantung kepada saiz kuantiti yang ditempah, (2) jumlah jualan produk independen bergantung kepada harga dan diskaun produk-produk lain dan (3) kesemua produk mesti dijual secara pukal. Akhir sekali, untuk mengatasi masalah ketiga, fungsi baru bahan tambah berat, yang dapat menimbangkan kepentingan relatif bagi setiap objektif serta keadaan bersifat *fuzzy*, adalah dicadangkan untuk tangani model *fuzzy* multi-objektif dan menentukan kuantiti pesanan yang optimum kepada para pembekal dinilaikan dan mendapat tempat oleh kaedah NG.

Keputusan bagi pendekatan perbandingan menunjukkan bahawa hasil kaedah NG adalah lebih optimum daripada kaedah I.LI dan terkemudian itu merupakan lebih optimum daripada kaedah LI. Oleh itu, kaedah NG telah dipilih untuk diintegrasikan dengan model *fuzzy* multi-objektif. Model *fuzzy* multi-objektif telah diselesaikan oleh fungsi penambahan pemberat baru dan keputusan itu menunjukkan bahawa selain daripada mengambilkira kepentingan relatif matlamat tersebut, teknik terbaru itu juga dapat untuk menimbangkan keadaan bersifat *fuzzy*.

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I certify that an Examination Committee has met on 23 April 2009 to conduct the final examination of Omid Jadidi on his Master of Science thesis entitled "INTEGRATION OF AN IMPROVED GREY BASED METHOD AND FUZZY MULTI-OBJECTIVE MODEL FOR SUPPLIER SELECTION AND ORDER ALLOCATION" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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Date: 17 July 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

OMID JADIDI

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOMENCLATURE

LI	The grey based method proposed by Li et al. (2007)
I.LI	The improved version of the LI method
NG	The new grey based method proposed in this research
PI	Percentage of the improvement calculated by the comparative approach
SCM	Supply Chain Management
MvB	Make versus Buy
EOQ	Economic Ordering Quantity
MCDM	Multi-Criteria Decision Making
DMs	Decision Makers
AHP	Analytic Hierarchy Process
TVP	Total Value of Purchasing
ANP	Applied Analytic Network Process
MOMILP	Multi-Objective Mixed Integer Linear Programming
MADM	Multi-Attribute Decision Making
MODM	Multi-Objective Decision Making
TS	Total Sum
SAW	Simple Additive Weighting
WSM	Weighted Sum Model
WPM	Weighted Product Model
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
Z_k	Negative Objective for Minimization
Z_k^0	Aspiration Level for Objective Z_k that the DM Wants to Reach
Z_k^+	Maximum Value (worst solution) of Negative Objective Z_k

Z_k^-	Minimum Value of Negative Objective Z_k
g_x	Inequality Constraints
h_x	Equality Constraints
x	Vector of Optimization or Decision Variable
$\mu_{z_k}(x)$	Membership Function
$\sim$	Indicates the Fuzzy Environment
$\leq\sim$	Fuzzified Version of $\leq$
JIT	Just-In-Time
CBR	Case-Based-Reasoning
AI	Artificial Intelligence
CA	Cluster Analysis
DEA	Data Envelopment Analysis
ABC	Activity Based Costing
VAHP	Voting Analytical Hierarchy process
FST	Fuzzy Sets Theory
MP	Mathematical programming
GA	Genetic Algorithm
TCO	Total Cost of Ownership
BOCR	Benefits, Opportunities, Costs and Risks
SIP	Stochastic Integer Programming
P_j	Set of Suppliers Offering Product j
P'_j	Set of Suppliers Offering Item j as j'
P^*_j	Set of Suppliers Offering Item j as j^*
S_i	Set of Items Offered by Supplier i

$L_i^{'}$	Set of Price Levels of Supplier i for $j^{'}$
L_i^{*}	Set of Price Levels of Supplier i for j^{*}
$m_i^{'}$	The Number of Price Levels of Supplier i for $j^{'}$
m_i^{*}	The Number of Price Levels of Supplier i for j^{*}
$l^{'}$	Price Level for $j^{'}, 1 \leq l^{'} \leq m_i^{'}$
l^{*}	Price Level for $j^{*}, 1 \leq l^{*} \leq m_i^{*}$
$R_{ijl}^{'}$	Maximum Purchased Volume of Product $j^{'}$ from Supplier i at Price Level $l^{'}$
$R_{ijl}^{*'}$	Slightly Less than $R_{ijl}^{'}$
R_{ijl}^{*}	Maximum purchased volume of product j^{*} from supplier i at price level l^{*}
R_{ijl}^{**}	Slightly less than R_{ijl}^{*}
$C_{ijl}^{'}$	Purchasing Price of Product $j^{'}$ From Supplier i at Price Level $l^{'}$
C_{ijl}^{*}	Purchasing Price of Product j^{*} from Supplier i at Price Level l^{*}
W_i	The Overall Score of the Supplier i Obtained from the Grey Based Method that is Equal to Γ_i
$X_{ijl}^{'}$	Number of Product $j^{'}$ Ordered from Supplier i at Price Level $l^{'}$
X_{ijl}^{*}	Number of Product j^{*} Ordered from Supplier i at Price Level l^{*}
X_{ij}	Number of Product j Ordered from Supplier i
q_{ij}	Expected Defect Rate of Product j for Supplier i
V_{ij}	Capacity of Supplier i for Product j
D_j	Demand of Product j

Y'_{ijl}	1 if an Order is Placed on Supplier i at Price Level l' for Product j', 0 Otherwise
Y^*_{ijl}	1 if an Order is Placed on Supplier i at Price Level l^* for Product j^*, 0 Otherwise
Y^*_{il}	1 if All the Special Products Are Ordered on Supplier i at Price Level l^*, 0 Otherwise
Y_i	1 if at Least an Order is Placed on Supplier i, 0 Otherwise
Q_γ	Set of $(\gamma = 1,2,...,\theta)$ Attributes of Suppliers
W_γ	Vector of Attribute Weights
$G_{i\gamma}$	Vector of Attribute Rating
$G^*_{i\gamma}$	Vector of Normalized Attribute Rating
$V_{i\gamma}$	Vector of Weighted Normalized Attribute Rating
C_i	Final Rating of Suppliers Calculated by Improved Li's et al Method
Γ_i	Final Rating of Suppliers Calculated by Simple Grey Based Method

CHAPTER 1

INTRODUCTION

1.1. Background of Study

With the globalization of the economic market, the development of information technology and high consumer expectations for quality products and short lead-times, companies have to take advantage of any opportunity to optimize their business processes. Many companies believe that a well-designed and implemented supply chain management (SCM) system is an important tool for increasing competitive advantage (Aissaouia et al., 2007; Li et al., 2007; Choi et al., 2007). To optimize these business processes, practitioners and academics have reached to the same judgment: for handling and maintaining a competitive position, companies have to work with their supply chain partners to improve the chain's total performance. Therefore, being the main process in the upstream chain and affecting all areas of an organization, the purchasing function and its associated decisions are taking an increasing importance (Aissaouia et al., 2007). Fig.1.1 illustrates that the major purchasing decision processes can be classified into six parts: (1) make or buy, (2) supplier selection, (3) contract negotiation, (4) design collaboration, (5) procurement, and (6) sourcing analysis (Aissaouia et al., 2007).

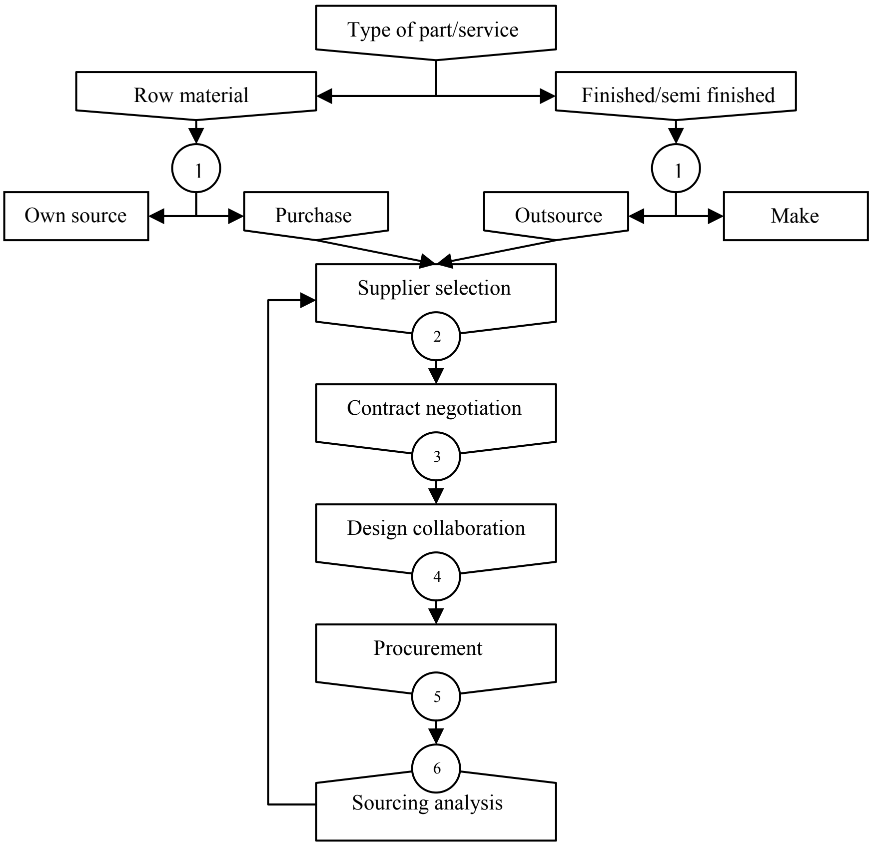

Fig. 1.1. Major Purchasing Processes (Aissaouia et al., 2007)

In Fig.1.1, the term 'outsourcing' is used for the case when a finished/semi-finished part or service is being purchased and the term 'purchasing' is also used for the case when a raw material is being purchased.

The make or buy decision process (Platts et al., 2002) (see stage 1, Fig. 1.1): in this process, an essential question in the development of a manufacturing strategy has always been the determination of what a company will make and what it will buy. However, with the advent of the information age, allowing businesses to communicate with each other with unprecedented speed and efficiency, there is growing interest in this question. If the operations of a company can be continuously matched with those of its suppliers, a supply chain that is consisting of several companies can act as a more coherent, functional unit than was previously possible.

In this dynamic and less centralized business environment, many manufacturing companies have commenced to place much more emphasis on their make versus buy (MvB) decisions; that is, when a manufacturer is faced with the design and production of a new process or component for one of its products, does it make it in-house, or does it buy it from another company?

The next process is supplier selection (Ustun and Demirtas, 2008b) (see stage 2, Fig. 1.1). One or a set of suppliers is chosen for procurement according to a predefined set of criteria or factors. Single sourcing and multiple sourcing are two kinds of supplier selection problem. For single sourcing, the management needs to select the best supplier, whereas for multiple sourcing he or she needs to divide order quantities among the selected suppliers. The contract negotiation process (see stage 3, Fig. 1.1) discusses the problem of designing a suitable contract. In the design collaboration (see stage 4, Fig. 1.1) stage, the purchaser and supplier work closely to design services and/or parts that meet quality standards and customer specifications.

In the procurement decision process (see stage 5, Fig. 1.1), the problem of guaranteeing that the suppliers would deliver the service and/or part in time and with minimum costs is discussed. Finally, in the sourcing analysis (see stage 6, Fig. 1.1) stage, the overall efficiency of a company procurement process is assessed. This stage would consider issues like assortments (ordering a group of service or and part from a single supplier), consolidation (shipping orders from more than one supplier together), and supplier performance measurements.