Invited Review

Multi-criteria decision making approaches for supplier evaluation and selection: A literature review

William Ho *, Xiaowei Xu, Prasanta K. Dey

Operations and Information Management Group, Aston Business School, Aston University, Birmingham B4 7ET, United Kingdom

1. Introduction

The contemporary supply management is to maintain long term partnership with suppliers, and use fewer but reliable suppliers. Therefore, choosing the right suppliers involves much more than scanning a series of price list, and choices will depend on a wide range of factors which involve both quantitative and qualitative. Extensive multi-criteria decision making approaches have been proposed for supplier selection, such as the analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids.

There are at least three journal articles reviewing the literature regarding supplier evaluation and selection models (Weber et al., 1991; Degraeve et al., 2000; De Boer et al., 2001). Since these articles review the literature up to 2000, this paper extends them by surveying the multi-criteria supplier evaluation and selection approaches through a literature review and classification of the international journal articles from 2000 to 2008. Based on the 78 journal articles collected (searched via Emerald, Ingenta, MetaPress, ProQuest, and ScienceDirect), three issues are examined, including: (i) Which approaches were prevalently applied? (ii) Which evaluating criteria were paid more attention to? (iii) Is there any inadequacy of the approaches?

The paper is organized as follows: Sections 2 and 3 describe the individual approaches and integrated approaches critically, respectively. Section 4 analyses the most prevalently used approaches, discusses the most popular evaluating criteria, and find out the limitations of the approaches. Section 5 suggests for future work. Section 6 concludes the paper.

2. Individual approaches

2.1. Data envelopment analysis

Fourteen out of seventy-eight articles (17.95%) applied DEA in the supplier selection process. Their applications and evaluating criteria used in the approaches are summarized in Appendix 1.

Based on the work in Baker and Talluri (1997), Braglia and Petroni (2000) applied DEA to measure the efficiencies of alternative suppliers. Nine evaluating factors were proposed to measure each supplier rating. To avoid selecting a sub-optimal or “false positive” supplier, both cross-efficiency and Maverick index were measured.

Liu et al. (2000) proposed a simplified DEA model to evaluate the overall performances of suppliers with respect to three input and two output criteria. The model aimed at selecting a supplier having higher supply variety so that the number of suppliers can be reduced.

Forker and Mendez (2001) applied DEA to measure the comparative efficiencies of suppliers. For each supplier, a measure of comparative efficiency was calculated as the maximum ratio of a...
single input to multiple outputs. Those outputs were based on the
critical factors of quality management proposed by other scholars.
Similar to Braglia and Petroni (2000), the cross-efficiencies were
calculated to find the “best peer” suppliers.

Narasimhan et al. (2001) applied DEA model to evaluate alter-
native suppliers for a multinational corporation in the telecommu-
nications industry. Eleven evaluating factors were considered in
the model, in which there are six inputs related to the supplier
capability, and five outputs related to the supplier performance.
Based on the performance score, the suppliers were classified into
four categories: high performers and efficient, high performers and
inefficient, low performers and efficient, and low performers and
inefficient.

Talluri and Baker (2002) used a three-phase approach for the
logistics distribution network design. Potential stakeholders,
including suppliers, manufacturers, and distributors were evalu-
ated individually in Phase I using DEA. The authors used six evalu-
ating factors proposed by other scholars for supplier evaluation, in
which there are two inputs and four outputs. Based on the perfor-
mance scores obtained in Phase I and the optimal number of stake-
holders to be utilized obtained in Phase II, the optimal routing of
material from selected suppliers to manufacturers to warehouses
were identified.

Talluri and Sarkis (2002) applied DEA to measure the per-
fomance of suppliers. The authors used the same evaluating factors
and dataset as that in Talluri and Baker (2002) to illustrate how
the model works.

Talluri and Narasimhan (2004) applied DEA for effective sup-
plier sourcing. The approach is similar to that in Narasimhan
et al. (2001), except that Narasimhan et al. (2001) used simple effi-
ciency scores in the analysis, whereas Talluri and Narasimhan
(2004) used cross-efficiencies and statistical methods in categoriz-
ing the supply base into various clusters.

Garfamy (2006) applied DEA to measure the overall perfor-
mances of suppliers based on total cost of ownership concept. A
supplier providing a single unit of output charging the least
amount of costs was regarded as the most efficient.

Ross et al. (2006) used DEA to evaluate the supplier perfor-
mance with respect to both buyer and supplier performance attrib-
utes. Three sensitivity analyses were carried out. The first analysis
was to compute the supplier efficiency scores without considering
the evaluation team’s weights and bounds. The second analysis
considered the evaluation team’s preferences on the supplier perfor-
ance attributes, whereas the third analysis considered the buyer’s preferences on the supplier performance attributes.

Saen (2006) developed a DEA model to evaluate technology
suppliers with respect to three factors, in which there was a qual-
itative factor – amount of know-how transfer. A five-point scale
was deployed to rank the suppliers in terms of the qualitative factor.

Seydel (2006) used DEA to tackle the supplier selection prob-
lem. Unlike the above approaches, there was no input considered
in the model. A seven-point scale was deployed to assign ratings
to the qualitative criteria. The author addressed that the proposed
DEA required less involvement of decision makers than SMART.

Talluri et al. (2006) presented a so-called chance-constrained
DEA approach to evaluate the performance of suppliers in the pres-
ence of stochastic performance measures. Price was considered as
an input, whereas quality and delivery were used as outputs. The
model was compared with the deterministic DEA to highlight its
usefulness.

Saen (2007a) presented a so-called imprecise DEA to evaluate
the performance of suppliers in the presence of both quantitative
and qualitative data. The author addressed that the supplier reputa-
tion (SR), one of the output measures considered in the case
study, could not be quantified legitimately. The proposed model al-
lowed the decision makers to provide a complete rank ordering of
the suppliers on SR. Besides, the proposed model could handle the
fuzzy data in the forms of bounded data.

Wu et al. (2007) presented a so-called augmented imprecise
DEA for supplier selection. The proposed model was able to handle
imprecise data (i.e., to rank the efficient suppliers) and allow for in-
creased discriminatory power (i.e., to discriminate efficient suppliers
from poor performing suppliers). A web-based system was
developed to allow potential buyers for supplier evaluation and
selection.

2.2. Mathematical programming

Among 78 journal articles, nine papers (11.54%) formulated the
supplier selection problem as various types of mathematical pro-
gramming models. Their applications and evaluating criteria used
in the approaches are summarized in Appendix 2.

2.2.1. Linear programming

Talluri and Narasimhan (2003) is the first group of researchers
considering performance variability measures in evaluating alter-
native suppliers. The researchers developed two linear program-
ming models to maximize and minimize the performance of a
supplier against the best target measures set by the buyer. Measur-
ing both maximum and minimum efficiencies of each supplier
would achieve a comprehensive understanding of a supplier per-
formance.

Talluri and Narasimhan (2005) developed a linear programming
model to evaluate and select potential suppliers with respect to the
strengths of existing suppliers and exclude underperforming sup-
pliers from a telecommunications company’s supply base. The
model was compared with traditional and advanced DEA to exam-
ine its relative advantages.

Ng (2008) developed a weighted linear programming model for
the supplier selection problem, with an objective of maximizing
the supplier score. Similar to AHP, it involves the decision makers
in determining the relative importance weightings of criteria.

2.2.2. Integer linear programming

Talluri (2002) developed a binary integer linear programming
model to evaluate alternative supplier bids based on ideal targets
for bid attributes set by the buyer, and to select an optimal set of
bids by matching demand and capacity constraints. Based on four
variations of model, effective negotiation strategies were proposed
for unselected bids.

Hong et al. (2005) presented a mixed-integer linear program-
ning model for the supplier selection problem. The model was to
determine the optimal number of suppliers, and the optimal order
quantity so that the revenue could be maximized. The change in
suppliers’ supply capabilities and customer needs over a period
of time were considered.

2.2.3. Integer non-linear programming

Ghodsypour and O’Brien (2001) formulated a mixed integer
non-linear programming model to solve the multi-criteria sourcing
problem. The model was to determine the optimal allocation of
products to suppliers so that the total annual purchasing cost could
be minimized. Three constraints were considered in the model.

2.2.4. Goal programming

Karpak et al. (2001) constructed a goal programming (GP) mod-
el to evaluate and select the suppliers. Three goals were considered
in the model, including cost, quality, and delivery reliability. The
model was to determine the optimal amount of products ordered,
while subjecting to buyer’s demand and supplier’s capacity
constraints.
2.2.5. Multi-objective programming

Narasimhan et al. (2006) constructed a multi-objective programming model to select the optimal suppliers and determine the optimal order quantity. Five criteria were proposed to evaluate the performance of suppliers. Before solving the model to optimality, the relative importance weightings of five criteria were derived from the possible ways for generating the weightings.

Wadhwa and Ravindran (2007) modeled the supplier selection problem as a multi-objective programming problem, in which there are three objective functions, such as minimization of price, lead time, and rejects. Three solution approaches, including weighted objective method, goal programming method, and compromise programming, were used to compare the solutions.

2.3. Analytic hierarchy process

There are seven (8.97%) out of 78 journal articles proposing AHP to deal with the supplier selection problem. Their applications and evaluating criteria used in the approaches are summarized in Appendix 3.

Akarte et al. (2001) developed a web-based AHP system to evaluate the casting suppliers with respect to 18 criteria. In the system, suppliers had to register, and then input their casting specifications. To evaluate the suppliers, buyers had to determine the relative importance weightings for the criteria based on the casting specifications, and then assigned the performance rating for each criterion using a pairwise comparison.

Muralidharan et al. (2002) proposed a five-step AHP-based model to aid decision makers in rating and selecting suppliers with respect to nine evaluating criteria. People from different functions of the company, such as purchasing, stores, and quality control, were involved in the selection process.

Chan (2003) developed an interactive selection model with AHP to facilitate decision makers in selecting suppliers. The model was so-called because it incorporated a method called chain of interaction, which was deployed to determine the relative importance of evaluating criteria without subjective human judgment. AHP was only applied to generate the overall score for alternative suppliers based on the relative importance ratings.

Chan and Chan (2004) applied AHP to evaluate and select suppliers. The AHP hierarchy consists of six evaluating criteria and 20 sub-factors, of which the relative importance ratings were computed based on the customer requirements.

Liu and Hai (2005) applied AHP to evaluate and select suppliers. Similar to Chan (2003), the authors did not apply the AHP’s pairwise comparison to determine the relative importance ratings among the criteria and sub-factors. Instead, the authors used Noguchi’s voting and ranking method, which allowed every manager to vote or to determine the order of criteria instead of the weights.

Chan et al. (2007) developed an AHP-based decision making approach to solve the supplier selection problem. Potential suppliers were evaluated based on 14 criteria. A sensitivity analysis using Expert Choice was performed to examine the response of alternatives when the relative importance rating of each criterion was changed.

Hou and Su (2007) developed an AHP-based decision support system for the supplier selection problem in a mass customization environment. Factors from external and internal influences were considered to meet the needs of markets within the global changing environment.

2.4. Case-based reasoning

Same as AHP, seven papers (8.97%) used CBR to evaluate and select suppliers. Their applications and evaluating criteria used in the approaches are summarized in Appendix 4.

Choy and Lee (2002) presented a generic model using the CBR technique for supplier selection. Various evaluating criteria were grouped into three categories: technical capability, quality system, and organizational profile. The model was implemented in a consumer products manufacturing company, which had stored the performance of past suppliers and their attributes in a database system. The proposed model would then retrieve or select a supplier who met the specification predefined by the company most.

Choy et al. (2002), Choy and Lee (2003), Choy et al. (2003a), Choy et al. (2003b), Choy et al. (2004a), Choy et al. (2005) applied the CBR-based model to aid decision makers in the supplier selection problem again. The approach was very similar to that proposed in Choy and Lee (2002), including the supplier selection workflow. In addition, the model was deployed to the same company. The only difference is due to the supplier evaluating factors, as shown in Appendix 4.

2.5. Analytic network process

Three papers (3.85%) proposed ANP to tackle the supplier selection problem. Their applications and evaluating criteria used in the approaches are summarized in Appendix 5.

Sarkis and Talluri (2002) believed that supplier evaluating factors would influence each other, and the internal interdependency needed to be considered in the evaluation process. The authors applied ANP to evaluate and select the best supplier with respect to organizational factors and strategic performance metrics, which consist of seven evaluating criteria. The impact of these factors among themselves was considered.

Bayazit (2006) proposed an ANP model to tackle the supplier selection problem. There were ten evaluating criteria in the model, which were classified into supplier’s performance and capability clusters. To formulate interrelationships among all criteria, each of them was considered as a controlling factor for a pairwise comparison matrix.

Gencer and Gürpinar (2007) implemented an ANP model in an electronic company to evaluate and select the most appropriate supplier with respect to various supplier evaluating criteria, which were classified into three clusters. The interrelationships among the criteria were considered in the selection process.

2.6. Fuzzy theory

Three papers (3.85%) utilized fuzzy set theory in the supplier selection process. Their applications and evaluating criteria used in the approaches are summarized in Appendix 6.

Chen et al. (2006) presented a hierarchy model based on fuzzy-sets theory to deal with the supplier selection problem. The linguistic values were used to assess the ratings and weights for the supplier evaluating factors. These linguistic ratings could be expressed in trapezoidal or triangular fuzzy numbers. The proposed model was capable of dealing with both quantitative and qualitative criteria.

Sarkar and Mohapatra (2006) suggested that performance and capability were two major measures in the supplier evaluation and selection problem. The authors used the fuzzy set approach to account for the imprecision involved in numerous subjective characteristics of suppliers. A hypothetical case was adopted to illustrate how the two best suppliers were selected with respect to four performance-based and ten capability-based factors.

Florez-Lopez (2007) picked up 14 most important evaluating factors from 84 potential added-value attributes, which were based on the questionnaire response from US purchasing managers. To obtain a better representation of suppliers’ ability to create value for the customers, a two-tuple fuzzy linguistic model was illustrated to combine both numerical and linguistic information.
Besides, the proposed model could generate a graphical view showing the relative suitability of suppliers and identifying strategic groups of suppliers.

2.7. Simple multi-attribute rating technique

Two papers (2.56%) used SMART to solve the supplier selection problem. Their applications and evaluating criteria used in the approaches are summarized in Appendix 7.

Barla (2003) conducted a five-step approach based on SMART for supplier evaluation and selection in a glass manufacturing company. In the methodology, seven evaluating criteria were proposed, of which there were multiple sub-factors to be considered. A subcontractor getting the highest score, called the total expected utilities, would be selected.

Huang and Keska (2007) presented a comprehensive set of 101 metrics, collected from the literature, for supplier selection. Instead of using all metrics, the authors selected some of the relevant criteria and metrics for the selection process.

2.8. Genetic algorithm

There is only one paper (1.28%) using GA in the supplier selection process. Its application and evaluating criteria used in the approach are summarized in Appendix 8.

Ding et al. (2005) presented a GA-based optimization methodology for supplier selection. The proposed method provided possible configurations of the selected suppliers, including transportation modes. Each configuration was then evaluated with respect to the key performance indicators.

3. Integrated approaches

3.1. Integrated AHP approaches

Fourteen papers (17.95%) applied integrated AHP approaches to evaluate the performance of suppliers and select the best supplier. Their applications and evaluating criteria used in the approaches are summarized in Appendix 9.

3.1.1. Integrated AHP and Bi-negotiation

Chen and Huang (2007) integrated AHP and a multi-attribute negotiation mechanism for the supplier selection problem. The model enabled the buyers and suppliers to negotiate on multi-attributes for a deal, including assets, business criteria, cost, and delivery.

3.1.2. Integrated AHP and DEA

Ramanathan (2007) suggested that DEA could be used to evaluate the performance of suppliers using both quantitative and qualitative information obtained from the total cost of ownership and AHP. Specifically, costs based on the concept of total cost of ownership were regarded as inputs, whereas the AHP weights were considered as outputs in the DEA model.

Saen (2007b) proposed an integrated AHP-DEA approach to evaluate and select slightly non-homogeneous suppliers. The author stated that many suppliers do not comprehensively consume common inputs to comprehensively supply common outputs. In the approach, AHP was deployed to determine the relative weight of each supplier that had missing value (i.e., input or output). DEA was then applied to compute the relative efficiency of each supplier.

Sevikli et al. (2007) applied an integrated AHP-DEA approach for supplier selection. In the approach, AHP was used to derive local weights from a given pairwise comparison matrix, and aggregate local weights to yield overall weights. Each row and column of the matrix was assumed as a decision making unit (DMU) and an output, respectively. A dummy input that had a value of one for all DMUs was deployed in DEA to calculate the efficiency scores of all suppliers. However, the authors pointed out that the approach was relatively more cumbersome to apply than the individual AHP.

3.1.3. Integrated AHP, DEA, and artificial neural network

Ha and Krishnan (2008) applied an integrated approach in an auto parts manufacturing company for supplier selection. Twelve evaluating criteria were proposed for the selection problem. In the approach, AHP was used first to evaluate the performance of suppliers with respect to five qualitative factors. Then, the remaining seven quantitative criteria along with the scores for each supplier calculated by AHP were passed to DEA and artificial neural network (ANN) to measure the performance efficiency of each supplier. Both results were compiled into one efficiency index using a simple averaging method.

3.1.4. Integrated AHP and GP

Çebi and Bayraktar (2003) proposed AHP to evaluate the relative performance of suppliers for every raw material with respect to 14 evaluating criteria. The weightings of suppliers were then used as the input of a GP model to select the best set of suppliers for a particular type of raw materials, and determine the amount of raw materials to be purchased.

Similar to Çebi and Bayraktar (2003), Wang et al. (2004, 2005) applied an integrated AHP-GP approach for supplier selection. The only difference between them is due to the evaluating criteria used in AHP. The AHP weightings were incorporated into one of the goal constraints of the GP model.

Perçin (2006) applied an integrated AHP-GP approach for supplier selection. AHP was used first to measure the relative importance weightings of potential suppliers with respect to 20 evaluating factors. The weightings were then used as the coefficients of five objective functions in the GP model. The model was to determine the optimal order quantity from the most appropriate supplier while considering the capacities of potential suppliers.

Kull and Talluri (2008) utilized an integrated AHP-GP approach to evaluate and select suppliers with respect to risk factors and product life cycle considerations. In the proposed model, AHP was used to assess suppliers along the risk criteria, and to derive risk scores. The GP model was then constructed to evaluate alternative suppliers based on multiple risk goals and various hard constraints.

Mendoza et al. (2008) presented an integrated AHP-GP approach to reduce a large number of potential suppliers to a manageable number, rank the alternative suppliers with respect to five evaluating criteria, and determine the optimal order quantity.

3.1.5. Integrated AHP and grey relational analysis

Yang and Chen (2006) applied AHP to compute relative importance weightings of qualitative criteria. The weightings were then used as coefficients of grey relational analysis model. The model would combine the qualitative and quantitative data to yield the grey relational grade values. A supplier with the highest value was regarded as the best supplier.

3.1.6. Integrated AHP and mixed integer non-linear programming

Mendoza and Ventura (2008) proposed a two-stage method to deal with the supplier selection and order quantity problems simultaneously. At the first stage, AHP was applied to rank and reduce a list of suppliers to a manageable number with respect to five evaluating criteria, as suggested by Mendoza et al. (2008).
Second, the mixed integer non-linear programming model was constructed to determine the optimal order quantity.

3.1.7. Integrated AHP and multi-objective programming

Xia and Wu (2007) incorporated AHP into the multi-objective mixed integer programming model for supplier selection. The model applied AHP to calculate the performance scores of potential suppliers first. The scores were then used as coefficients of one of the four objective functions. The model was to determine the optimal number of suppliers, select the best set of suppliers, and to determine the optimal order quantity.

3.2. Integrated fuzzy approaches

Nine papers (11.54%) proposed integrated fuzzy approaches to deal with the supplier evaluation and selection problem. Their applications and evaluating criteria used in the approaches are summarized in Appendix 10.

3.2.1. Integrated fuzzy and AHP

Kahraman et al. (2003) applied a fuzzy AHP to select the best supplier in a Turkish white good manufacturing company. Decision makers could specify preferences about the importance of each evaluating criterion using linguistic variable.

Chan and Kumar (2007) also used a fuzzy AHP for supplier selection as the case with Kahraman et al. (2003). In the approach, triangular fuzzy numbers and fuzzy synthetic extent analysis method were used to represent decision makers' comparison judgment and decide the final priority of different criteria.

3.2.2. Integrated fuzzy, AHP, and cluster analysis

Bottani and Rizzi (2008) developed an integrated approach for supplier selection. The approach integrated cluster analysis and AHP to group and rank alternatives, and to progressively reduce the amount of alternatives and select the most suitable cluster. Fuzzy logic was also brought in to cope with the intrinsic qualitative nature of the selection process.

3.2.3. Integrated fuzzy and GA

Jain et al. (2004) suggested a fuzzy based approach for supplier selection. The authors addressed that it might be difficult for an expert to define a complete rule set for evaluating the supplier performance. GA was therefore integrated to generate a number of rules inside the rule set according to the nature and type of the priorities associated with the products and their supplier's attributes.

3.2.4. Integrated fuzzy and multi-objective programming

Amid et al. (2006) developed a fuzzy multi-objective linear programming model for supplier selection. The model could handle the vagueness and imprecision of input data, and help the decision makers to find out the optimal order quantity from each supplier. Three objective functions with different weights were included in the model. An algorithm was developed to solve the model.

Amid et al. (in press) formulated a fuzzy multi-objective mixed integer linear programming model to solve the supplier selection problem. The approach is very similar to that in Amid et al. (2006), including the number of objective functions in the model, the criteria used to evaluate the suppliers, and the solution approach used to solve the model. The only difference is that quantity discount was considered in Amid et al. (in press). The price discount was directly proportional to the quantities ordered.

3.2.5. Integrated fuzzy and quality function deployment

Bevilacqua et al. (2006) applied quality function deployment (QFD) approach for supplier selection. A house of quality was constructed to identify the features that the purchased product should have in order to satisfy the customers' requirements, and then to identify the relevant supplier assessment criteria. The importance of product features and the relationship weightings between product features and assessment criteria were assigned in terms of fuzzy variables. Finally, the potential suppliers were evaluated against the criteria.

3.2.6. Integrated fuzzy and SMART

Kwong et al. (2002) integrated fuzzy set theory into SMART to assess the performance of suppliers. The supplier assessment forms were used first to determine the scores of individual assessment items, and then the scores were input to a fuzzy expert system for the determination of supplier recommendation index.

Chou and Chang (2008) applied a fuzzy SMART approach to evaluate the alternative suppliers in an IT hardware manufacturing company. A sensitivity analysis was carried out to assess the impact of changes in the risk coefficients in terms of supplier ranking order.

3.3. Other approaches

Many other integrated approaches (nine papers or 11.54%) were proposed. Their applications and evaluating criteria used in the approaches are summarized in Appendix 11.

3.3.1. Integrated ANN and CBR

Choy et al. (2003c, 2004b) developed an integrated ANN and CBR approach to select the best supplier. Specifically, ANN was used to benchmark the potential suppliers, whereas CBR was used to select the best supplier based on the previous successful and relevant cases.

3.3.2. Integrated ANN and GA

Lau et al. (2006) developed an integrated ANN and GA approach for supplier selection. ANN was responsible for benchmarking the potential suppliers with respect to four evaluating factors. After that, GA was deployed to determine the best combination of suppliers. The four evaluating criteria were used again in the fitness function of GA.

3.3.3. Integrated ANP and multi-objective programming

Demirtas and Üstün (2008) developed an integrated ANP and multi-objective mixed integer linear programming approach to select the best set of suppliers, and to determine the optimal order allocation. Performance of potential suppliers was evaluated using ANP against 14 assessment criteria. The priorities were then incorporated into one of the three objective functions.

3.3.4. Integrated ANP and GP

Demirtas and Üstün (2009) developed an integrated ANP and GP approach for supplier selection. Similar to Demirtas and Üstün (2008), potential suppliers were evaluated using ANP first. The weightings were then used as coefficients of one of the three objective functions. All evaluating criteria and objective functions are exactly the same as those in Demirtas and Üstün (2008). The only difference is that a GP model was constructed in which there were four goals.

3.3.5. Integrated DEA and multi-objective programming

Weber et al. (2000) constructed a multi-objective programming model to determine the optimal order quantity. Three objective functions were incorporated into the model. The optimal solution was then used as an input in a DEA model, which was to measure the efficiency effect of the constraints in the multi-objective programming model on the alternative suppliers.
Talluri et al. (2008) utilized a combination of input oriented DEA and multi-objective programming models to determine the negotiation strategies with efficient suppliers. The approach enables effective tailoring of supplier specific negotiations by benchmarking the performance of each potential supplier against the performance of existing suppliers.

3.3.6. Integrated DEA and SMART

Seydel (2005) applied SMART approach to evaluate the performance of 10 suppliers. Instead of choosing among suppliers, DEA was applied to evaluate the results of decision making, and to identify a set Pareto efficient outcomes from among a set of candidates.

3.3.7. Integrated GA and multi-objective programming

Liao and Rittscher (2007) formulated a multi-objective programming model for supplier selection under stochastic demand conditions. Four objective functions were incorporated into the model. Instead of solving the model to optimality, GA was deployed to select the optimal supplier in an efficient manner.

4. Observations and recommendations

In this paper, 78 journal articles, which appeared in the period from 2000 to 2008, solving the supplier evaluation and selection problem using the multi-criteria decision making approaches were collected. The approaches, including individual and integrated, their applications and evaluating criteria have been summarized in Appendices 1–11. Some observations based on these journal articles are made in the following subsections.

4.1. The most popular approach

The first objective of this paper is to find out the most popular approach adopted in supplier evaluation and selection literature. As found in the previous sections, the individual approaches (46 papers or 58.97%) were slightly more popular than the integrated approaches (32 papers or 41.03%).

According to Appendix 12, the most popular individual approach is DEA, followed by mathematical programming, AHP, CBR, ANP, fuzzy set theory, SMART, and GA. DEA has attracted more attention mainly because of its robustness. In the past, it was used to measure the relative efficiencies of homogeneous DMUs based on numerical data only. As the supplier selection problem involves both qualitative and quantitative criteria, DEA has been modified to handle qualitative data, such as amount of know-how transfer (Saen, 2006), service (Seydel, 2006), supplier reputation (Saen, 2007a), and so on. In addition, it can now be used to consider stochastic performance measures (Talluri et al., 2006), and handle imprecise data (Saen, 2007a; Wu et al., 2007).

As shown in Appendix 13, there are various integrated approaches for supplier selection. It was noticed that the integrated AHP approaches are more prevalent. The wide applicability is due to its simplicity, ease of use, and great flexibility (Ho, 2008). AHP has been integrated with other techniques, including ANN, bi-negotiation, DEA, fuzzy set theory, GP, grey relational analysis, and multi-objective programming. Comparatively, the integrated AHP–GP approach is the most popular. The major reason is that the individual techniques possess unique advantages. The consistency verification operation of AHP contributes greatly to prevent inconsistency because it acts as a feedback mechanism for the decision makers to review and revise their judgments. Consequently, the judgments made are guaranteed to be consistent, which is the basic ingredient for making good decisions. Nevertheless, the output of AHP is the relative importance weightings of criteria and sub-factors merely. In supplier selection problem, besides the weightings of alternative suppliers, the decision makers also need to consider the resource limitations (e.g., budget of buyer and capacities of suppliers). For this reason, the GP can compensate for AHP. It can definitely provide more and useful information for the decision makers. Based on the above analysis, it is believed that it must be beneficial to the decision making process if both AHP and GP are integrated together.

4.2. The most popular evaluating criterion

The second objective of this paper is to discover the most popular criterion considered by the decision makers for evaluating and selecting the most appropriate supplier. Hundreds of criteria were proposed, and they were summarized in Appendix 14. The most popular criterion is quality, followed by delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment.

There are 68 papers (87.18%) considering quality in the supplier selection process. Various quality related attributes have been found in the papers, such as “acceptable parts per million”, “compliance with quality”, “continuous improvement program, six sigma program or total quality management program”, “corrective and preventive action system”, “documentation and self-audit”, “inspection and control”, “ISO quality system installed”, “low defect rate”, “net rejections”, “non-conforming material control system”, “number of bills received from the supplier without errors”, “number of quality staff”, “percentage of products or items not rejected upon inspection”, “perfect rate”, “process control capability”, “quality assurance production”, “quality award”, “quality certification”, “quality data and reporting”, “quality manual”, “quality planning”, “quality management practices and systems”, “reliability of quality”, “rejection in incoming quality”, “rejection in production line”, “rejection from customers”, “service quality credence”, “service quality experience”, “shipment quality”, and “training”.

The second most popular criterion is delivery (64 papers or 82.05%). Its related attributes include “appropriateness of the delivery date”, “compliance with due date”, “degree of closeness”, “delivery and location”, “delivery compliance”, “delivery conditions”, “delivery delays”, “delivery efficiency”, “delivery lead time”, “delivery mistakes”, “delivery performance”, “delivery reliability”, “distance”, “geographical condition”, “geographical location”, “net late deliveries”, “number of shipments to arrive on time”, “order-to-delivery lead time”, “on-time delivery”, “percentage of orders shipped to buyer on or before original promised ship date”, “percentage of orders shipped on or before final ship date”, “percentage of orders delivered by the due date”, “sample delivery time”, “supplier proximity”, and “waiting time”.

The third most popular criterion price/cost (63 papers or 80.77%). Its related attributes include “appropriateness of the materials price to the market price”, “competitiveness of cost”, “cost reduction capability”, “cost reduction effort”, “cost reduction performance”, “direct cost”, “fluctuation on costs”, “indirect-coordination cost”, “logistics cost”, “manufacturing cost”, “unit cost”, “ordering cost”, “parts price”, “product price”, and “total cost of shipments”.

Based on the above findings, it was revealed that price/cost is not the most widely adopted criterion. The traditional single criterion approach based on lowest cost bidding is no longer supportive and robust enough in contemporary supply management.

4.3. Limitations of approaches

The last objective of this paper is to critically analyze the approaches, and try to find out some drawbacks. Instead of analyzing...
every single approach, the main focus of this section is confined to DEA and AHP–GP, which are the two most popular individual and integrated approaches, respectively. The reasons why these two approaches have attracted more attention can be found in Section 4.1.

There are three limitations or drawbacks of DEA. First, the practitioners may be confused with input and output criteria. For example, some authors considered price/cost as an output criterion (Naransimhan et al., 2001; Talluri and Narasimhan, 2004; Seydel, 2006), whereas the others used it as an input criterion (Liu et al., 2000; Naransimhan et al., 2001; Talluri and Baker, 2002; Talluri and Sarkis, 2002; Talluri and Narasimhan, 2004; Garfamy, 2006; Ross et al., 2006; Saen, 2006, 2007a; Talluri et al., 2006; Wu et al., 2007). The second problem is due to the subjective assignment of ratings to qualitative criteria. Although Saen (2006) and Seydel (2006) deployed five-point and seven-point scales to rank the priorities of qualitative criteria, respectively, some inconsistencies may be occurred because of the subjective judgments. The third concern is due to the nature of DEA. As discussed earlier, DEA is a linear programming to measure the relative efficiencies of homogenous DMUs. In the other words, those suppliers generating more outputs while requiring less input are regarded as the more efficient suppliers. A question is raised “is an efficient supplier equivalent to an effective supplier?”

In the integrated AHP–GP approach, AHP was used first to determine the relative importance weightings of alternative suppliers with respect to multiple evaluating criteria. The weightings were then incorporated into the GP model to determine the optimal set of suppliers to be selected, and determine the optimal order quantity, while subjecting to some resource constraints. There is one potential problem related to AHP. It may be time-consuming in reaching consensus. Decision makers have to compare each cluster in the same level in a pairwise fashion based on their own experience and knowledge. For instance, every two criteria in the second level are compared at each time with respect to the goal, whereas every two sub-factors of the same criteria in the third level are compared at a time with respect to the corresponding criterion. If it is found that the consistency ratio exceeds the limit, the decision makers have to review and revise the pairwise comparisons again.

4.4. Other observation

The distribution of the 78 journal articles between 2000 and 2008 is shown in Appendix 15. It is observed that there is a growth in the study of the supplier evaluation and selection problem using the multi-criteria decision making approaches from the first 5 years (2000–2004) to the recent 4 years (2005–2008), 31 vs. 47. It is estimated that the number will keep increasing in the coming years because of the importance of supplier selection to an effective supply chain.

5. Future work

Although the above mentioned approaches can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business objectives and requirements of company stakeholders on the evaluating criteria. In reality, the weightings of supplier evaluating criteria depend a lot on business priorities and strategies. In cases where the weightings are assigned arbitrarily and subjectively without considering the “voice” of company stakeholders, the suppliers selected may not provide what the company exactly wants.

To enable the “voice” of company stakeholders is considered, an integrated analytical approach, combining AHP and QFD, should be developed to select suppliers strategically. Specifically, multiple evaluating criteria are derived from the requirements of company stakeholders using a series of house of quality. The importance of evaluating criteria is prioritized with respect to the degree of achieving the stakeholder requirements using AHP. Based on the ranked criteria, alternative suppliers are evaluated and compared with each other using AHP again to make an optimal selection.

The most important information that the QFD provides is the importance weightings of evaluating criterion, which are derived by the importance ratings of stakeholder requirements together with the relationship weightings between stakeholder requirements and evaluating criterion. Generally, both importance ratings of stakeholder requirements and relationship weightings are determined by the decision makers arbitrarily. This may result in a certain degree of inconsistency, and therefore degrade the quality of decisions made. To overcome this drawback, AHP is used to evaluate them consistently. Nevertheless, the proposed AHP–QFD approach has not been applied to the supplier selection problem yet.

6. Conclusions

This paper is based on a literature review on the multi-criteria decision making approaches for supplier evaluation and selection from 2000 to 2008. First, it was found that numerous individual and integrated approaches were proposed to solve the supplier selection problem. They are all capable of handling multiple quantitative and qualitative factors. The most prevalent individual approach is DEA, whereas the most popular integrated approach is AHP–GP. Second, it was observed that price or cost is not the most widely adopted criterion. Instead, the most popular criterion used for evaluating the performance of suppliers is quality, followed by delivery, price or cost, and so on. This proves that the traditional single criterion approach based on lowest cost is not supportive and robust enough in contemporary supply management. The traditional cost-based approach cannot guarantee that the selected supplier is global optimal because the customer-oriented criteria (quality, delivery, flexibility, and so on) were not considered. Besides, some recommendations were made based on the inadequacies of some approaches. This can definitely aid the researchers and decision makers in solving the supplier selection problem effectively.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2009.05.009.

References


