CHAPTER 2
MULTI CRITERIA DECISION MAKING APPROACHES FOR GREEN SUPPLIER EVALUATION AND SELECTION: A LITERATURE REVIEW

A large and growing body of literature to supplier evaluation and selection exists. Literature on green supplier evaluation that considers environmental factors are relatively limited. Recently, in supply chain management decision making, approaches for evaluating green supplier performance have used both qualitative and quantitative environmental data. Given this evolving research field, the goal and purpose of this study is to analyze research in international scientific journals and international conference proceedings that focus on green supplier selection. In this study, the following questions will be answered: (i) which selection approaches are commonly applied? (ii) what environmental and other selection criteria for green supplier management are popular? (iii) and what limitations exist? Published research from 1997 to 2014 is structurally reviewed based on the first two questions. From the study it has been found that the applied techniques are mostly fuzzy based single model approaches. The most common criterion considered for green supplier selection was “environmental management systems”. A further critical analysis is completed and gaps in the current literature are identified. These gaps help us to identify improvements for green supplier selection process and possible future directions.
2.1  INTRODUCTION

Supplier selection is a key operational task for developing sustainable supply chain partnerships. Environmental, social, and economic dimensions must all be considered in order to select a well-rounded sustainable supplier, one that can enhance supply chain performance. Part of the supplier selection process involves supplier evaluation together with selection, which is an important issue to supply chain and production and operation management literature (Motwani & Youssef 1999).

Currently, due to outsourcing initiatives, organizations have become more dependent on suppliers making it more critical to choose and evaluate their supplier performance. Supplier evaluation and selection requires the consideration of multiple objectives and criteria (Bhutta & Huq 2002). Research has been robust in this field with study including adopting approaches and implementation from a wide range of mathematical practices and methodologies. Consequently, numerous multi-criteria decision support tools have been developed for structuring and supporting such decisions (Wu et al 2010). Typically, when organizations seek to develop or choose a supplier evaluation and selection method, the organization’s specific requirements are introduced. Therefore, model flexibility and a choice from a range of different selection methods with different applications are needed.

One such topic of increasing interest is the green, environmental supply chain management issues. This area involves and screens suppliers based on their organizational environmental performance, and distinguish whether a certain supplier’s performance is baseline (e.g. meeting regulatory requirements) or advanced (e.g. collaborative green product design) practice (Rao 2002). Traditionally, environmental protection issues were considered in the production process along with traditional supplier selection criteria.
Due to this current environmental awareness, suppliers have adopted many green policies and practices.

Recent established research has utilized supplier selection mechanisms which consider environmental protection issues (Humphreys et al 2003a; Yeh & Chuang 2011). A potentially effective way of managing a company’s environmental policy is by linking it closely with purchasing function activities, i.e. through supplier selection (Humphreys et al 2003a). Provisional guidelines for environmentally evaluating the suppliers have existed for some time (Lamming & Hampson 1996). In support of these early efforts, environmental performance measurement frameworks were also introduced (Noci 1997; Hervani et al 2005). Noci (1997) identified performance criteria to consider in the green supplier selection process and suggested techniques for effective supplier selection from an environmental viewpoint. Shen et al (2013) proposed a fuzzy approach for evaluating the green suppliers. Also, Hervani et al (2005) provided an integrative framework which focuses on study, design, and evaluation aspects of green supply chain management performance tools.

This study carefully examines green supplier selection papers that appeared from 1996-2014 in international scientific journals available in electronic databases such as Elsevier’s Science Direct, Emerald Publishers, Springer, IEEE, Taylor & Francis, and Google Scholar. This research analyzes the papers published in international conference proceedings and summarizes the contributions made by researchers on green supplier selection at the conferences. The following keywords were used to search the databases: green supplier evaluation, green supplier selection, green supply chain management, green criteria, and supplier selection. This study examines and highlights the methodologies and environmental criteria utilized. As of first
major objective, this study analyze multi-criteria decision-making approaches such as the analytical hierarchy process (AHP), analytical network process (ANP), case based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming and their hybrids. The second objective is an analysis of the green criteria used, including issues such as green products, green knowledge transfer, green image, recycling, environmental management systems, environmental certificates, and other criteria utilized in green supplier selection models. This information is useful to researchers and practitioners by clearly pointing to applicable tools and content (performance measures) that have and could be applied to environmental supplier selection. A critical analysis will be helpful in guiding future research and application, and in clearly identifying the capabilities, boundaries, and limitations of the tools.

This chapter begins in Section 2.2 by giving an overview of research and literature on supplier selection and green supplier selection. Section 2.3 describes the review methodology followed by the classification method presented in Section 2.4. Section 2.4 also summarizes the literature based on multi-criteria decision making approaches and environmental criteria for the selection process. Section 2.5 presents an observation by the discussion about the most prevalently used approaches and most popular evaluation criteria considered for the selection process. Section 2.6 discusses the results and future work from this study and Section 2.7 focuses on drawing final conclusions of this study.

2.2 SUPPLIER SELECTION AND GREEN SUPPLIER SELECTION

Research in supplier selection has gained particular importance over the past few decades as organizations started to focus on issues of core
competence and to outsource less profitable activities to supply chain partners (Arnold 2000; Lonsdale & Cox 2000; Quinn 1999). This evolution included a more strategic focus on the buyer-supplier relationship where close collaboration was necessary and certain skills and capabilities were required (Sarkis & Talluri 2002).

These skills and capabilities required greater scrutiny by buyer organizations, which led to the more complex tasks of identifying and selecting strategic supply chain partners because some suppliers have limited capacity or other constraints (Kannan et al 2013). This real world complexity in the outsourcing and vendor selection process generated the need to help organizations make more thoughtful and simplified decisions. Simplifying complex managerial decision making is the role of many pragmatic theories and models (Williamson 2008).

Models for supplier selection represent only one of over a dozen supply chain management areas (see Badole et al (2013) for a comprehensive review of supply chain modelling literature). Thus, it is easy to see that a strategic direction in supplier management practices requires the ability to take multiple criteria and measures in order to arrive at a clear and straightforward prioritization or final selection (Ho et al 2010). The extensive nature and modelling complexity of the regular supplier selection process makes the problem heavily reliant on multiple criteria decision models.

Multiple criteria decision making is not only for the purposes of simplification and arriving at a clear decision, but it also allows researchers and management to balance a variety of criteria, many of them conflicting (Sarkis & Talluri 2002; Chai et al 2012). This level of complexity and
trade-offs is even more evident when it includes the additional dimensions of greening of supply chains (Bai & Sarkis 2010b).

Environmental and economic trade-offs are common place in organizational decision making, whether it is based on supplier selection or other management decisions such as technology and product selection (Ajukumar & Gandhi 2013; Khalili & Duecker 2013; Sarkis 2003; Sarkis et al 2012). The trade-offs are typically based on a variety of operational and strategic sustainability metrics that need careful integration, with or without management input.

The supplier selection process has only recently (within the last decade) started to integrate various environmental dimensions. The decision models will necessarily become more complex due to the many new dimensions brought in by green supply chain efforts, where the trade-offs become more evident and numerous. The decisions will also include more intangible dimensions such as reputation, supply chain risk, business continuity, and social impact. These new criteria and dimensions required rethinking some of the more established approaches and models. In addition, decision makers, or agents that influence the decisions, continue to grow when environmental factors come into play (Herva & Roca 2013). Extended stakeholder influence, input, and considerations all start to play a larger role in green supply chain management (Govindan et al 2013a; Sarkis et al 2012; Bai & Sarkis 2010a). Whether these issues are captured in the evolving models is something to consider as this study provide the review. Before reviewing and critically examining the growing literature in green supplier selection, this study introduces the methodology; partake to select the research that study seeks to review.
2.3 RESEARCH METHODOLOGY

Literature reviews are valuable comprehensive studies used to investigate research in emergent fields and to help guide future research and directions (Lage Junior & Godinho Filho 2010; Govindan 2013; Govindan et al 2013b). This study presents the following research methodology:

Step 1: Perform a literature review regarding green supplier evaluation and selection.

Step 2: Develop a classification framework using methodology and criteria.

Step 3: Segregate and tabulate the literatures based on the framework

Step 4: Present the literature review using the classification framework to organize the review.

Step 5: Analyze the review and present suggestions for future work.

To accomplish this study’s objectives, this research examines journals that incorporate a number of green supply chain management studies. The literature review is a usual method to investigate thoroughly different approaches of the topic to be studied (Lage Junior & Godinho Filho 2010). Peer-reviewed academic journals and proceedings are most commonly used to acquire information and report new research findings (Ngai et al 2008; Lage Junior & Godinho Filho 2010). Forty papers appearing from 1996-2014 are targeted using various publisher and publicly available electronic databases, including 18 papers of Elsevier’s Science Direct (45.00%), 4 papers of Emerald Publishers (10.00%), 3 papers of Springer (7.50%), 12 papers of IEEE (30.00%), 3 papers of Taylor & Francis (7.50%) publications, and the Google Scholar database. The following keywords were used in some form in the search databases: green supplier evaluation, green supplier selection, green supply chain management, green criteria, and supplier selection.
2.4 A CLASSIFICATION

After collecting the literature, a classification framework (Figure 2.1) is constructed. This research focuses only on green supplier selection in which environmental criteria is taken into account. Hence, the traditional criterion has not been considered in this research. The classification is based on two main categories:

a) Decision making methodology base
   (i) Individual methodology approach
   (ii) Integrated methodology approach
b) Criteria selection base
   (iii) Environmental criteria base

Figure 2.1 Classification framework for green supplier evaluation and selection review

The remainder of this section focuses on each of the various categories identified in this classification framework.

2.4.1 Multi-Criteria Decision-Making – Individual Methodology Approach

Researchers have developed many tools for multiple criteria decision making, and many of the latest integrate fuzzy logic. From the
analysis of articles, the research has applied multi-criteria decision-making approaches in both individual and integrated ways. A summary of the multi-criteria decision-making approaches, using an authorship ordering, applied to green supplier selection is given in Table A2.1.

2.4.1.1 Analytical Hierarchy Process (AHP)

Six out of forty (15.0%) journal articles are identified as propose AHP (including fuzzy AHP, FEAHP) for green supplier selection process. The practical applications and evaluating criteria used in these approaches are summarized in Table A2.2.

Noci (1997) proposed an AHP based method for assessing a vendor’s environmental efficiency. The tool was applied in an automotive case using five steps to calculate suppliers’ capabilities to achieve high environmental performance; suppliers who achieved the highest scores were preferable and recommended for selection.

Handfield et al (2002) illustrated the case of AHP as a decision support tool to help managers understand the trade-offs between environmental dimensions. They demonstrated how AHP can be used to evaluate the relative importance of various environmental traits and to access the relative performance of several suppliers along with the traits.

Lu et al (2007) applied AHP to evaluate and coordinate green suppliers in a project environment. A weighting system using a fuzzy logic process is used to modify AHP.

Chiou et al (2008) also adjusted AHP and applied FAHP for selection of green suppliers using 6 criteria with 24 sub-criteria. The tool application was to determine the relative importance of selecting green
suppliers across a multicultural setting including American, Japanese, and Taiwanese electronic industries in China.

Lee et al (2009) applied FAHP integrated with the Delphi method for green supplier evaluation. The Delphi method was initially used to differentiate the criteria for evaluating traditional and green suppliers. FAHP is used to solve the green supplier selection process; they focused on the efficiencies of FAHP. They used 11 main criteria and 41 sub criteria.

Grisi et al (2010) implemented a fuzzy AHP for green supplier evaluation using a 7 step approach. Fuzzy logic was adopted to overcome uncertainty arising from human qualitative judgment.

2.4.1.2 Analytic Network Process (ANP)

Four papers (10.0%) in this review data set proposed ANP to handle the green supplier evaluation and selection process. The illustrative application and evaluation criteria in these papers are summarized in Table A2.3.

Hsu & Hu (2007, 2009) applied ANP for green supplier selection to further incorporate interdependencies among decision structure components. Their argument was that ANP captures both quantitative and qualitative criteria, reflecting a more realistic result offering managerial insights while selecting suppliers systematically.

Büyüközküan and Çifçi, (2010, 2011) developed a novel approach based on a fuzzy ANP model within a multi-person decision making scheme under incomplete preference relationships. This method's advantages allows
for sufficient evaluation by using the provided preference information and maintaining the evaluation consistency.

2.4.1.3 Mathematical programming

One article in the review data set (2.5%) proposes mathematical programming for the green supplier selection process. The application and evaluating criteria used in the approaches are summarized in Table A2.4.

Yeh & Chuang (2011) developed an optimal mathematical planning model for green partner selection which involves four objectives. They adopted two multi-objective genetic algorithms (MOGA) to find the set of Pareto-solution, which is utilized the weighted sum approach and compared the average number of Pareto operational solution and CPU times of the two algorithms.

2.4.1.4 Other approaches

Sixteen papers (40.0%) in the data set propose other approaches, and their application setting and evaluating criteria are summarized in Table A2.5.

Zhang et al (2003) proposed a fuzzy multi-agent decision making strategy to facilitate supplier management. They evaluate the environmental performance of the suppliers and the life cycle environmental impact of a purchased product.

Vachon & Klassen (2006) applied Chi-Square Test for exploring the operational performance of green partnership in the supply chain. In this
study, the data from the survey was used for testing the linkage between the
green project partnership and five performance indicators.

Humphreys et al (2006) proposed the fuzzy based system for green
supplier selection based on the quantitative and qualitative environmental
criteria. The major benefit of this system is its computational parsimony. The
proposed system is capable of implementing a range of user priorities that
influences to varying degrees the system output. The hierarchical fuzzy
system, with scalable fuzzy membership functions employed, imparts user
priorities into the system that can weakly or strongly influence the supplier
selection process.

Yang & Wu (2007) constructed a multi-level grey entropy synthetic
evaluation model for evaluation of a green supplier. The evaluation process
indicates that it was easier to implement the method in enterprises. The main
aspect of this model was that fewer hierarchy weight factors were needed.
Arguably, their result is more objective than other evaluation methods.

Yang & Wu (2008) developed a multi-level extensible synthetic
evaluation model based on the grey entropy synthetic evaluation model for
green supplier evaluation. This model overcomes the lower weight factor
avoidance and the result was more objective than the other evaluation
methods.

Bai & Sarkis (2010a; b) applied Rough set methodology which
utilizes an incomplete information approach which is more realistic in some
data poor environments for green supplier development. There is also a
limitation and practical managerial concerns with this multi-criteria decision-
making approach in which the number of rules can become quite large
depending on the volume of the data which is to be analyzed.
Kumar & Jain (2010) proposed a comprehensive approach DEA for green supplier selection using carbon footprint monitoring. This approach cuts across a huge variety of supplier base and caters to almost all businesses as environmentally friendly and robust. The approach encourages suppliers to go with green and to cut down their carbon footprints in order to survive the competition.

Hong-jun & Bin (2010) applied factor analysis identifying main factors for green supplier selection. The factor analysis is used to confirm the indices weights of each level, avoiding managerial subjectivity associated with tools such as AHP. Limitations include varying indices across different industries and sample bias which may affect the conclusions.

Fezioğlu & Büyüközkör (2010) proposed a multi-criteria evaluation model, using the Choquet Integral approach for supplier performance evaluation. The important feature of this operator is its ability to take into account criteria dependencies. The proposed method is more appropriate when compared to other methods that used only arithmetic means.

AwASTHI et al (2010) proposed an approach using three steps: identification of criteria, experts rating, and assessment of experts rating through a fuzzy TOPSIS methodology. The methodology ranks the supplier alternatives based on environmental performance, recommending selection of the highest valued alternative. An advantage of the fuzzy TOPSIS approach is its integration of benefits and cost criteria. Sensitivity analysis was conducted in this study to evaluate the influence of criteria weights on the environmental performance evaluation of the suppliers. The approach is relatively practical and can provide a solution under partial lack of quantitative information.
Large & Thomson (2011) developed a Structural Equation Model by degree of green criteria which explains the environmental performance and the purchasing performance. The model was analyzed with SmartPLS 2.0 software using data collected by the survey.

Chiou et al (2011) developed a structural equation model for the data analysis which is used to implement the proposal for green innovation in order to improve the environmental performance and to enhance the competitive advantage in the global market of the company.

Hsu et al (2013) utilized DEMATEL approach to improve the overall performance of the green supplier in terms of carbon management. This study considers thirteen criteria of carbon management and revealed the top significant influences in selection of green suppliers with carbon management competencies.

Kannan et al (2014) develops green supplier evaluation and selection framework using fuzzy TOPSIS approach for electronics industry. This study built the framework on the criteria of green supply chain management practices.

2.4.2 Multi Criteria Decision Making – Integrated Methodology Approach

From the review, it has been found that only thirteen papers (32.2%) used integrated approaches (summarized in Table A2.6).

Humphreys et al (2003a) implemented a Knowledge Based System (KBS) using Case based reasoning (CBR). This approach integrates the environmental criteria into the green supplier selection process and provides
the guidelines for purchasing managers to select suppliers from an environmental point of view.

Li & Zhao (2009) used a threshold method and grey correlation analysis for the assessment of an index system for the supplier of vehicle components. They use AHP to determine weight of factors for the comprehensive assessment. The grey relational analysis evaluates the correlation between the factors.

Yan (2009) proposed an integrated approach adopting a genetic algorithm and AHP to achieve green supplier optimization evaluation and selection. The author introduces a genetic algorithm combined with current weights of a supplier to dynamically adjust weights determined from AHP. The supplier evaluation indicators become more evident and optimized, while the system can dynamically adjust over time for a better supplier evaluation indicator.

Kuo et al (2010) developed a green supplier selection model which integrates Artificial Neural Network (ANN), Multi Attribute Decision Analysis (MADA), Data Envelopment Analysis (DEA) and ANP. From the study, it has been discovered that ANN-MADA has better power of discrimination and noise insensitivity in evaluating a green supplier’s performance. It also overcomes the DEA’s drawbacks and limitations of data accuracy and decision making units among constraints.

Wen & Chi (2010) introduced DEA into the assessment of green supplier selection combined with AHP to establish an integrated model. This model overcomes the limitation of an individual approach of the traditional tools such as AHP and ANP for evaluation of suppliers. In this model, DEA
filters suppliers to lessen the supplier set. AHP/ANP can then proceed more efficiently on the smaller subset.

Thongchattu & Siripokapirom (2010) applied AHP for green supplier selection, which allows the decision maker to structure complex problems. Added to the AHP model, the author proposed the consensus final decision using ANN.

Chen et al (2010) apply fuzzy set theory accompanied with grey relational analysis for green supplier selection. The proposed method uses linguistic preference structures for deriving priorities for alternatives and uses grey numbers in all criteria and alternatives to avoid criteria limitations.

Kuo & Lin (2011) proposed a method which integrates ANP and DEA for green supplier evaluation. DEA and ANP consider the interdependency between the criteria. It expands on DEA by allowing users to restrict the weights using their own criteria weight preferences. This approach also allows for more flexibility on the number of decision making units (DMUs) used.

Büyüközkan & Çifçi (2012) proposed fuzzy MCDM model combines the fuzzy DEMATEL, ANP and TOPSIS for appropriate green supplier evaluation and selection process. In this approach fuzzy DEMATEL and ANP approaches used to determine the interdependent relationship within and among a set of criteria and fuzzy TOPSIS approach helped to identify the appropriate green supplier.
Büyüközkan (2012) proposed an integrated approach of fuzzy AHP and fuzzy AD to identify the appropriate green supplier. The proposed group decision making model considers various environmental performance criteria.

Shaw et al (2012) proposed an integrated approach of FAHP and MOLP methodology to identify appropriate green supplier in low carbon supply chain management. This study mainly focuses on reduction of carbon emission in the supply chain through order allocation among the green suppliers.

Kannan et al (2013) applied FAHP, FTOPSIS approaches for green supplier evaluation and selection, and MOLP for order allocation among the green suppliers in integrated way. This study deal with multiple sourcing problem which includes green supplier selection and allocation of optimal order quantity for selected suppliers.

Bali et al (2013) applied integrated approach of intuitionistic fuzzy set (IFS) and grey relational analysis (GRA) to handle the uncertainties in green supplier selection process. The novelty of this approach is to apply appropriate uncertainty method in various steps of selection process instead of applying same uncertainty theory in whole process.

2.4.3 **Environmental Criteria Based Supplier Selection**

A summary of the environmental criteria used by the research identified in this study appear in Appendices 2.2 to 2.6. The most widely considered criterion for green supplier selection is “environmental management system”. This major criterion is followed by green image, environmental performance, environmental competencies, design for environment, green competencies, corporate and social responsibilities,
environmental efficiency, environmental authentication, environmental improvement cost, green logistic dimension, green organization activities, environmental certification, suppliers’ green image, use of environmentally friendly material, use of environmentally friendly technology, waste management, re-use, re-cycle, green process innovation, green product, green purchasing, green project partnership and green design. A very large set of criteria, some of which overlap are utilized in various works.

Fourteen papers (35.0%) used environmental management system as a criterion for supplier selection process. Environmental management system is typically considered a main criterion, with sub-criteria such as environmental policies, environmental planning, and ISO14001 certification. These criteria are termed as qualitative environmental criteria and they required subjective decisions to be made during their evaluation. To summarize, most of the literature insists that the implementation of environmental management systems is a primary factor in identifying environmentally sound suppliers.

2.5 OBSERVATIONS AND RECOMMENDATIONS

In this review, forty journal articles related to green supplier evaluation and selection were collected and analyzed using multi-criteria decision-making approaches and evaluation criteria characteristics. This study presents some observations and a somewhat critical analysis of these initial findings in this section.

2.5.1 Widely Used Approaches

Researchers have developed and applied a variety of approaches for multi-criteria decision-making for the green supplier selection problem. One interesting characteristic is the preponderance of fuzzy analysis. Managerial
and contextual uncertainty makes for fuzziness in the decision making process, and ambiguity and intangibility cause difficulty in the analysis. This study seeks out the most popular approach adopted in the supplier evaluation and selection literature to provide insight into what is considered state-of-the-art. Interestingly, in many of the identified papers, twenty seven papers (67.5%) are still utilizing a single technique in their analysis. This may be due to the ease of focusing on only one approach and by deliberately limiting the complexity of the approaches. Thirteen papers (32.5%) utilized an integrated approach, with the objective of trying to achieve a more realistic application given the complexities of a real-world decision process.

The most popular individual approach was AHP followed by ANP, DEA, and other tools. As the supplier selection problem involves both qualitative and quantitative criteria, AHP not only can handle adequately the inherent uncertainty and impression of human decision making process, but also it can provide the robustness and flexibility needed for the decision maker to understand the decision problem. AHP shows the performance of a supplier with respect to each sub criteria and main criteria, so it shows the supplier status on each criterion. Also, mathematically and philosophically, AHP provides an easily understandable and defensible approach to practitioners. It allows practitioners to be involved in the analysis and actually to guide the decision more effectively. This managerial transparency and lack of complexity allow for greater acceptance by both researchers and practitioners.

AHP is not without its critics; however, so ample consideration should be given to its limitations. The growth and application of AHP may derive more from a convenience and simplification perspective rather than from a strong theoretical mathematical perspective. The utilization and integration of fuzzy techniques may be advantageous for some settings, but
criticism has also been targeted to the overreliance on fuzzy mathematics for these decision environments. For example, some studies have shown that the ultimate decisions from fuzzified AHP models do not provide any differences in the ultimate solution than regular AHP. The additional complexity of utilizing fuzzy numbers may be unnecessary. Additional research on the ultimate solution quality under fuzzy and regular numerical valuations is necessary to determine whether the addition of fuzzy logic is a worthwhile effort. This study conjecture that practitioners will choose basic AHP approaches over fuzzified approaches since regular AHP approaches are easier for the practitioners to understand and provide greater transparency. Investigating whether these additional complexities in modelling AHP are acceptable to practitioners is another avenue of potential research. MCDM approaches that were applied individually are summarized in Table A2.7.

This study observes various integrated approaches for supplier selection. From the analysis, it was noticed that integrated AHP is still a very popular approach. The integration of AHP with other techniques may also be tied to its easy to understand mathematical basis, ease of use, and flexibility. AHP has been integrated with DEA, ANN, GA, TOPSIS, and fuzzy set theory. The major reason for integration is that the individual techniques possess some unique advantages that allow for complementary contribution to the AHP approach. The consistency verification operation of AHP contributes greatly to prevent inconsistency because it acts as a feedback mechanism for the makers to review and revise the judgment. The MCDM which was applied in an integrated way is summarized in Table A2.8.

Yet, multiple techniques, especially for the unversed, can cause lack of practitioner acceptance due to their increased complexity. But some integrative approaches may overcome these limitations by actually simplifying
the ‘upfront’ process. For example, an initial filtration process reduces the number of alternatives and criteria, and may allow for lessened practitioner involvement. This type of situation is most evident when practitioner input is not needed for initial or later stages of multiple method techniques. Additional investigation into how multi-method techniques can be barriers or enablers to acceptance of certain integrative tools is certainly an important direction for future research.

2.5.2 Widely Used Evaluation Criterion

In most of the recent studies, both traditional and ecological criteria are considered for supplier selection. The second objective of this study is to discover the most popular criteria considered by the literature for evaluating and selecting the appropriate supplier. Hundreds of criteria were proposed and they are summarized in Table A2.9.

Quantitative environmental criteria articulated in economic terms and qualitative environmental criterion that focuses on more intangible (e.g. company image and reputation) have been used for supplier selection (Humphreys et al 2003a). This study has observed from the review data set that the major criteria considered are environmental management system and quality (Grisi et al 2010). Some studies are also based on potential drivers like GSCM capabilities, strategic level of purchasing department, the level of environmental commitment, degree of green supplier assessment and degree of green supplier collaboration (Large & Thomsen 2011).

In portfolio based analyses, pollution control and prevention are considered as environmental factors (Lee et al 2009). There is a study in effect with four drivers namely regulation, customer pressure, social responsibility, and business benefits on green purchasing (Büyüközkan & Çifçi, 2010, 2011).
Chen et al (2010) states that companies must engross suppliers and purchasers to congregate and even exceed the environmental expectation of their customers and their governments. Many manufacturing concerns organize through the outsourcing and thus the companies are vitally dependent on their suppliers. Most of the companies ask their suppliers to implement ISO14001 since the standard becomes a prevalent tool for environmental aspects and factors in the sustainable supply chain (social, economic and environmental) (Chen et al 2010; Büyüközyakan & Çifçi 2011).

The prevalence and shifting focus of environmental criteria add additional complexities for both practitioners and researchers. Although this study has mentioned about some researches that are try to target certain criteria, especially environmental ones, consensus criteria are difficult to come by. Jabbour and Jabbour (2009) analyzed the inclusion of environmental criteria in the supplier selection process at organizations; they verified that the organizations have difficulties including environmental aspects in the supplier selection process. Clearly, more generic and encompassing criteria (e.g. environmental management systems) implementation are more acceptable due to their flexibility. The difficulty in these situations is that their generality also leads to greater ambiguity in what criteria actually mean. Care needs to be taken when introducing these intangible and broad criteria, which cause greater uncertainty and trust in the data and results. It can also be frustrating to those suppliers who are influenced by the decisions these models recommend.

Additional research is required to identify and to more clearly define each of the criteria. Building accepted definitions and characteristics of these criteria before their implementation in decision models is necessary for the acceptance of the methodologies, and, most importantly, for the decisions
that derive from these methodologies. For example, the utilization of exploratory factor analysis of practitioners may be a way to help determine and categorize factors into various groupings. Also, methods for identifying, defining, grouping, and filtering criteria would greatly enhance the research, development, and application of models and their criteria. These areas are important and necessary directions.

2.6 RESULTS AND FUTURE WORK

From the review, it has been found that individual methodological approaches were used more than multiple integrated methodological approaches and environmental criterion were not precisely focused in many articles. Also, the weightings of supplier evaluating criteria depend on business priorities and strategies. In cases where the weightings are assigned arbitrarily and subjectively, this leads to the supplier selection that may not be accurate based on company requirements. Many approaches work for the primary selection of a suitable supplier, but do not necessarily recommend why that supplier is the best choice or why suppliers who fail in the selection process might improve their performance standings.

This study has also observed that sensitivity analysis was not completed in many circumstances. Sensitivity analysis investigates the impacts of criteria weights on the selection of supplier with best environmental performance by changing the weights of the criteria for several experiments. So, it has to be carried in future multi-criteria decision-making approaches. As part of a sensitivity analysis, the careful consideration of various stakeholder and multi-functional influences need integration. The unique characteristics of environmental and general sustainability dimensions means that inputs from a variety of stakeholders (e.g., communities, supplier’s suppliers, environmental consultants, and staff) may be necessary to help
address some of the more sensitive issues facing environmental performance and criteria of suppliers.

Moreover, this study has identified in the previous section additional avenues for further investigation, focusing primarily on the methodologies and criteria. These investigations need to include the level of acceptance of models by practitioners and researchers. Comparative analyses truly need to be completed. This comparative analysis needs to be both research and practically oriented. Validation, acceptance, and reliability of techniques are required for additional development. These investigations can clarify strengths and weaknesses that may not be observable to the developers and modelers.

Many researchers, even ourselves, may be biased for one approach or another. For scientific progress, additional investigations in experimental settings are needed, especially as the complexities of the environmental and ecological factors come into play. Interesting organizational and behavioural decision studies need to follow up on these prescriptive approaches. For example, longitudinally are these results associated with the greenest suppliers that are selected, confirmed months or years after the selection? Are the decisions that are made good ones? This type of research requires significant resources, patience, and a considerable degree of follow-up. It may also require unprecedented access to the decision maker and companies. This research is used to carefully examine these directions and strengthen the modelling effort.

2.7 CONCLUDING REMARKS

This study reviewed multi-criteria decision making approaches for supplier evaluation and selection in literature from 1997 to 2014. Many
individual and integrated approaches have been proposed for supplier selection. The literature review has highlighted that the implementation of green issues within the supplier selection process is limited as relatively few papers were identified. This study found that the most widely used multi-criteria decision-making approach is analytical hierarchy process (AHP) and the most widely considered criteria for green supplier evaluation and selection is environmental management system.

Besides some recommendations like crisp results in supplier selection, failure mode analysis for failed suppliers might be added to aid the researchers and decision makers in solving the green supplier selection problem effectively. Additionally, a sensitivity analysis should be conducted as a primary method of selecting a supplier with the best environmental performance; it should take into account changing weights and it should address sensitive data changes so that choosing the wrong supplier can be avoided. This study has also identified a number of potential, open ended, developmental, and research questions that focus on the validity of the models and criterion. The location application has to be tested and carried out to find the fitness of research. Substantial research in the behavioural and applied characteristics of these models is needed. This study contains some limitations, such as the extensiveness of the reviewed literature and the inclusion of the proceedings articles which were not peer reviewed.

The critical analysis that this study provides need to tie the model developers with behavioural decision making literature. Experimental designs, not just application validation, are needed for future research. This research could have tied in these additional multiple criteria decision analysis concerns, which may be even more evident in socially sensitive decisions such as green supplier selection.
There are ample opportunities for future investigations in a number of directions for this research. This research could have tied in these additional multiple criteria decision analysis concerns, which may be even more evident in socially sensitive decisions such as green supplier selection. This study hope established and younger scholars investigate many of these issues as the problems this study face from an environmental perspective infringe on our lives more than ever.

Based on the literature review, some of the research gaps are identified in the green supplier evaluation and selection issues which are already explained in the earlier chapter. In this research work, process industrial sector has been considered for case study and an appropriate multi criteria decision framework and solution methodologies are developed for green supplier evaluation and selection in process industries and are explained in forthcoming chapters.

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