ANP IN SUPPLY CHAIN MANAGEMENT

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SESSION ABSTRACT

In this session three papers will be presented. First paper is about third party logistics (3PL) companies. These companies are a becoming an important part of today's supply chain. A framework is proposed to select the best 3PL service provider using Analytical Network Process for an aerospace company located in a large Western Washington city.

Second paper identifies and prioritizes capabilities that are most likely to provide competitive advantage. Scholars have traditionally used Ordinary Least Squares (OLS) to understand the relationship between capabilities and firm performance. However, OLS is limited in its limited to explain the interdependences and connectedness amongst multiple firm capabilities themselves which is possible with ANP modelling. Thus in this paper integration of OLS and ANP methods in explaining interdependences amongst firm capabilities and their effect on firm performance are proposed.

Third paper is literature review on multiple criteria models used in supply networks. To evaluate developments and directions of this research area, this paper provides a content analysis of the papers reviewed that address sustainability aspects in the supply networks. It was found that a preponderance of the publications and models appeared in a limited set of six journals, and most were analytically based with a focus on multiple criteria decision making. Our preliminary research indicated that the tools most often used encompass the AHP and ANP as well as life cycle analysis. This provides insights toward future research directions and needs.

SELECTION OF A THIRD PARTY LOGISTICS SERVICE PROVIDER FOR AN AEROSPACE COMPANY: AN ANALYTICAL NETWORK PROCESS APPROACH

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ABSTRACT

Third party logistics (3PL) companies are a becoming an important part of today's supply chain. These companies offer services that can allow businesses to outsource part of all of their supply chain management function. As companies saw the benefits of outsourcing delivery and warehousing functions, the number of third party logistics companies began to rise offering an ever increasing number of services. Therefore deciding to outsource company's logistics operations is a challenging task and represents a multi criteria decision making problem. In this research, a framework is proposed to select the best 3PL service provider using Analytical Network Process for an aerospace company located in a large Western Washington city.

Keywords: 3PL service provider; 3PL service provider selection; logistics outsourcing; analytical network process; ANP.

1. Introduction

As the competition in global markets intensifies, companies started to seek ways to strengthen their position by concentrating on their core competencies. In today's fiercely competitive markets, companies outsource more of the other activities other than their core to outside firms. Logistics is a critical part of integrated supply chain and in recent years, companies began to outsource their logistics functions as a way to focus on their core competencies. Many companies are now outsourcing more of their logistics services and use 3PL providers that offer a wide range of logistics services including warehousing, order fulfillment, freight consolidation, packaging, inventory management, inbound/outbound freight, and more. A *2010 Global 3PL & Logistics Outsourcing Strategy* survey found out that 97% of shippers intend to increase their use of 3PLs in the future (3PLwire.com). According to the Council of Supply Chain Management Professionals (CSCMP), a 3PL "provides multiple logistics services for use by

customers. Preferably, these services are integrated, or bundled together, by the provider. Among the services 3PLs provide are transportation, warehousing, cross-docking, inventory management, packaging, and freight forwarding."

Meidute et al (2012) discusses that companies need to be careful regarding the decision to outsource the logistics operations. Companies need to carefully evaluate its alternatives to decide whether it is worth outsourcing all logistics functions or some to outside logistics service providers and what services to outsource. 3PL providers appear to be the key players in todays' supply chains. 3PLs once provided only logistics services to their clients. But over the years they have evolved from providing logistics services to being important orchestrators of supply chain (Zacharia *et al*, 2011). According to a study by Fulconis *et al* (2011), "3PL providers now play an essential part in the operation of supply chains and take over increasingly large intermediation tasks, from the running of conventional logistical operations to the running of postponement operations, and above all facilitating the pooling of logistical resources to the benefit of a network of interconnected supply chains". Once a company decides to outsource its logistics function, next step would be to choose the right 3PL provider. Deciding to use a 3PL depends on variety of quantitative and qualitative factors. Our synthesis of literature indicated that a number of factors have been identified in evaluating 3PL providers including but not limited to quality, financial stability, IT capabilities, flexibility, reputation, range of services, on-time delivery, compatibility, ability to develop long-term relationship, geographical coverage, trustworthiness and employee performance (Meade and Sarkis, 2002; Bottani and Rizzi, 2006; Bagchi and Mitra, 2006; McGinnis *et al.*, 1995; Qureshi *et al.*, 2008; Jharkharia and Shankar, 2007, Yan *et al.*, 2003; Langley, 2004).
In this research, we undertook a study to demonstrate how the ANP can be used in evaluating 3PL providers for an aerospace company located in a large Western Washington city. The ANP is a theory that extends the AHP to cases of dependence and feedback and provides a general framework for dealing with decisions without generating assumptions about the independence between levels of a hierarchy (Saaty, 2000). Therefore the ANP enabled us to construct a networking model involving interactions among various criteria. This paper is organized as follows: a literature review of previous studies is explained in the second section. This is followed by the methodology employed in the study through a case study. The paper concludes with a summary to highlight the important findings from the study and future research directions.

2. Literature Review

Different techniques and approaches have been used in the literature to evaluate 3PL providers. Daim et al. (2013) applied AHP for selecting a third party logistics (3PL) provider for an international business. Rajesh et al (2012) proposed a set of strategies for balanced scorecard of 3PL service providers. In the study, the weightages for the different strategies were evaluated using Delphi analysis. Generic balanced scorecard framework for third party logistics service provider. In another study, Kumar et al (2012) applied the two-phase methodology approach, using consistent fuzzy preference relation (CFPR) and vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) method to analyze a multi-criteria logistic outsourcing problem. A comprehensive framework for logistics outsourcing problem was developed and most appropriate third party logistic

(3PL) provider was selected for a medium-scale organization manufacturing automobile parts in northern India. Diego (2012) proposed a mathematical method that combines AHP, data envelopment analysis (DEA) and linear programming in order to support the multi-criteria evaluation of third party logistics service providers. The proposed model has been validated on the real case of an international logistics service provider. In a similar study, Li at al (2012) proposed an indicator system and a method for data integration by establishing a comprehensive evaluation model for 3PL suppliers based on fuzzy sets. Also a compound quantification model based on centralized quantification values, a comparison method based on the synthesis effect, and a 3PL supplier selection model were demonstrated through a real-world case analysis. Orrin et al (2012) used analytical network process (ANP) to select a 3PL provider among three alternatives for a multinational pharmaceutical company located in Pittsburgh.

Azadi and Saen (2011) demonstrated a DEA model for the third party reverse logistics provider selection process while allowing for the incorporation of output-oriented super slacks-based measure SBM model and stochastic data through a numerical example of twenty 3PL providers. Kayakutlu and Buyukozan (20121) used the analytic network process to assess the performance factors for 3PL companies. The framework is applied and studied in two major logistics companies active in the South East Europe. Qureshi *et al* (2008) demonstrated the use of fuzzy Multi-Criteria Decision Making (MCDM) methodology which uses fuzzy synthetic evaluation and TOPSIS methodology to evaluate the best 3PL services provider for a company operating in electric switchgear production.

3. Hypotheses/Objectives

In this research, we undertook a study to demonstrate how the ANP can be used in evaluating 3PL providers for an aerospace company located in a large Western Washington city.

4. Research Design/Methodology

Our purpose is to show how the analytic network process (ANP) can be used in aiding companies with the decision of selecting the most capable 3PL service provider for an aerospace company. Analytical network process (ANP) is a generalization of analytic hierarchy process for multiple criteria problems where there may be interdependence among criteria, alternatives. It again deals with decisions involving both qualitative as well as quantitative factors.

In the ANP we first,

1. Identify alternatives and factors affecting alternatives.
2. If there are m factors and n alternatives an influence matrix of m+n by m+n is formed by listing all the factors and alternatives in rows and columns of this matrix. Influence of each factor on the row (including the alternatives) upon a factor on column (including the alternatives) is determined by eliciting judgments from experts. If a factor *i* on the row influences another one in the column *j* we insert "+" in (*i, j)* cell of influence matrix otherwise leave it empty.

3. Factors are clustered into components. Clustering is preferable to reduce the number of comparisons, to keep pairwise comparisons in a manageable level for experts. This technical preference most of the time is a natural result of managerial decisions since these factors usually arise in clusters. Such as technical factors, social factors, cost factors etc. Alternatives forms one of the clusters. It is a good practice to name them as alternatives since the software, Superdecisions© (2013) considers it in the calculation process.
4. For every cluster, degree of influence of two factors on the row upon a factor on the column is elicited by using 9 point scale like in AHP if there is a "+" sign at the intersection of these rows with the column with a questionnaire. If there is only one "+" sign in any cluster for any column there is no need to make any pairwise comparisons.
5. Priority vectors are derived like AHP. The matrix consists of these priority vectors forms unweighted super matrix.
6. Every column in unweighted super matrix illustrates first degree of influence of each factor on the row upon a factor on the column. Since for each factor on the row there exists second, third, etc. degree of influences methodology captures those by raising the unweighted super matrix into second, third, ….n th power. Unweighted super matrix needs to be column stochastic to converge when it is raised into n th power. Again this mathematical requirement is also a natural result of managerial considerations since all clusters usually are not equally influential. Some are more influential than the others with respect to a controlling factor.
7. Influence of each cluster is determined by pairwise comparisons of the clusters.
8. Unweighted super matrix multiplied by the priorities of each cluster forms the weighted super matrix.
9. Rows of the weighted super matrix raised into n th power give the limit matrix.

5. Data/Model Analysis

We contacted a senior procurement manager for 3PL contracts who delivers logistics services to the aerospace company's production systems. Our expert, senior procurement manager for an aerospace company located in Western Washington, reduced alternative 3PL suppliers into manageable level by using SOW for an aerospace company located in Western Washington. After she explained the sourcing process, we realized that it is a multi-criteria decision making problem including both quantitative and qualitative criteria. Therefore we decided to run an ANP study on the problem in order to provide a systematic approach. She has extensive experience in handling 3PL service contracts, so she is highly suitable for our project considering the fact that managerial judgments are used to drive the ANP approach. First, we explained our objective and presented the ANP methodology to the senior procurement manager, since she was not familiar with the approach.

A 3PL service provider evaluation and selection requires a systematic approach which includes various steps. The aerospace company initiates the source selection decision with a specific statement of work (SOW) followed by creating a list of qualified companies from which to request a proposal for that SOW. The major filtering criteria that involve several must-have capabilities that enable the company to quickly narrow a large number of potential providers down to a manageable list of candidates include:

(i) Capacity and capability (range of services) that line up with the company's requirements.

(ii) Demonstrated successful performance to similar SOWs as measured by key performance indicators such as turn-around time, inventory accuracy, and so on.

(iii) Financial health

Those criteria mentioned above are used to make a bid list at the aerospace company. All of these criteria were cited as the major 3PL service provider selection criteria in the literature previously. However the aerospace company uses these criteria as the filtering criteria in their sourcing process. Before proposals for a SOW are received, the company determines source selection/evaluation criteria specific to that SOW. The manager mentioned that the company has three main criteria and several sub-criteria included under their "big three": (i) technical competence, (ii) schedule/timeliness and (iii) price/cost. Therefore she has identified three main criteria and several sub-criteria as source selection criteria specific to the SOW.

After identifying the criteria and alternatives with the help of our expert, influence matrix is formed by listing all the factors and alternatives in rows and columns of this matrix.

		Technical Competence				Schedule/Timeliness	Price/Cost		Alternatives		
		B1	B2	B3	B4	C1	D1	D2	A1	A2	A3
Technical Competence	B1					+		+	+	+	+
	B2								+	+	+
	B3				+				+	+	+
	B4								+	+	+
Schedule/Timeliness	C1								+	+	+
Price/Cost	D1								+	+	+
	D2								+	+	+
Alternatives	A1	+	+	+	+	+	+	+			
	A2	+	+	+	+	+	+	+			
	A3	+	+	+	+	+	+	+			

Figure 1. Influence Matrix

Non recurring cost and schedule/timeliness is influenced by proximity, ease of interface influenced by IT services capabilities.

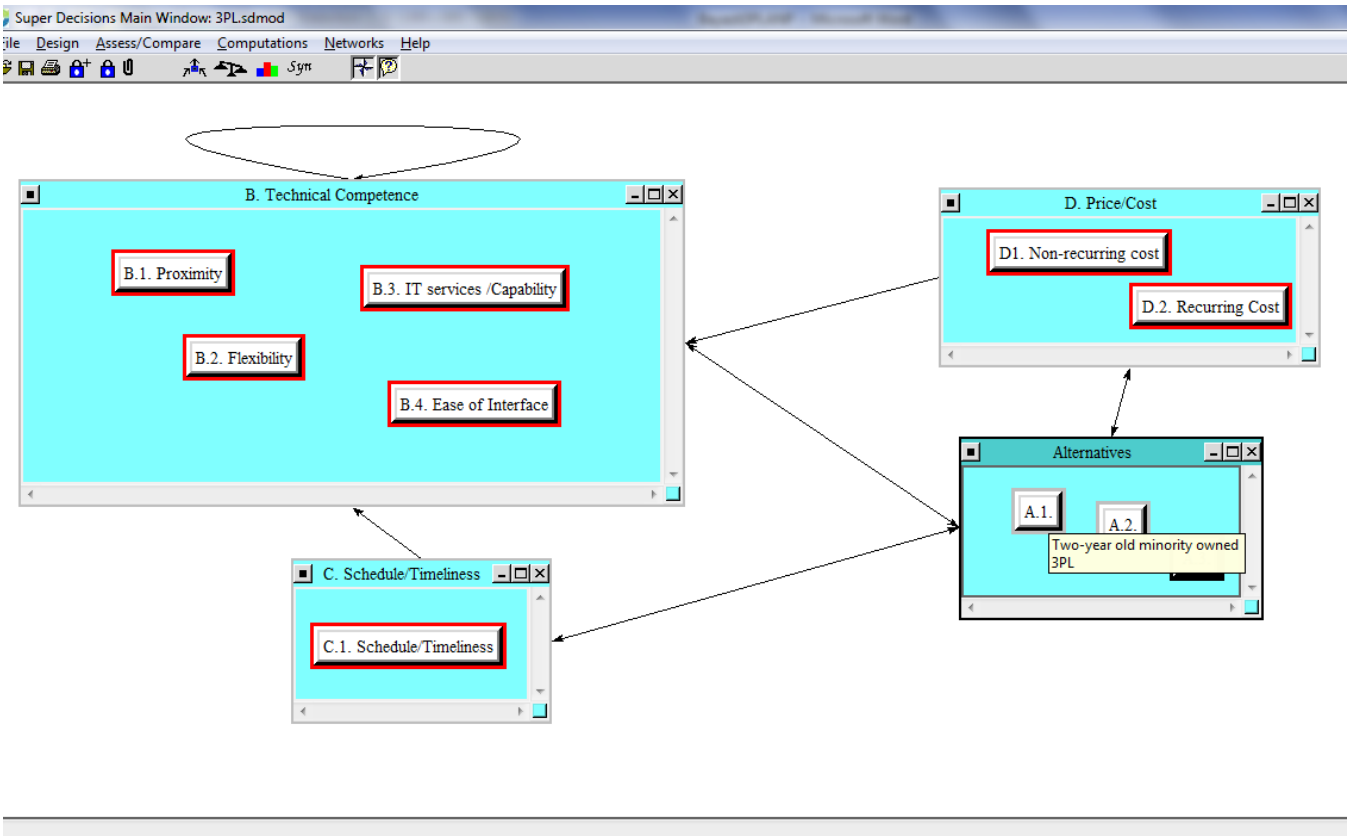

Figure 2. ANP model

Name	Priority
B. Technical Competence	0.258
C. Schedule/Timeliness	0.105
D. Price/Cost	0.637
Inconsistency	0.037

Table 1. Cluster comparisons with respect to alternatives

Name	Priority
B.1. Proximity	0.584
B.2. Flexibility	0.158
B.3. IT services /Capability	0.187
B.4. Ease of Interface	0.071
Inconsistency	0.003

Table 2. Proximity is the most influential factor of Alternative 3 in Technical competence cluster

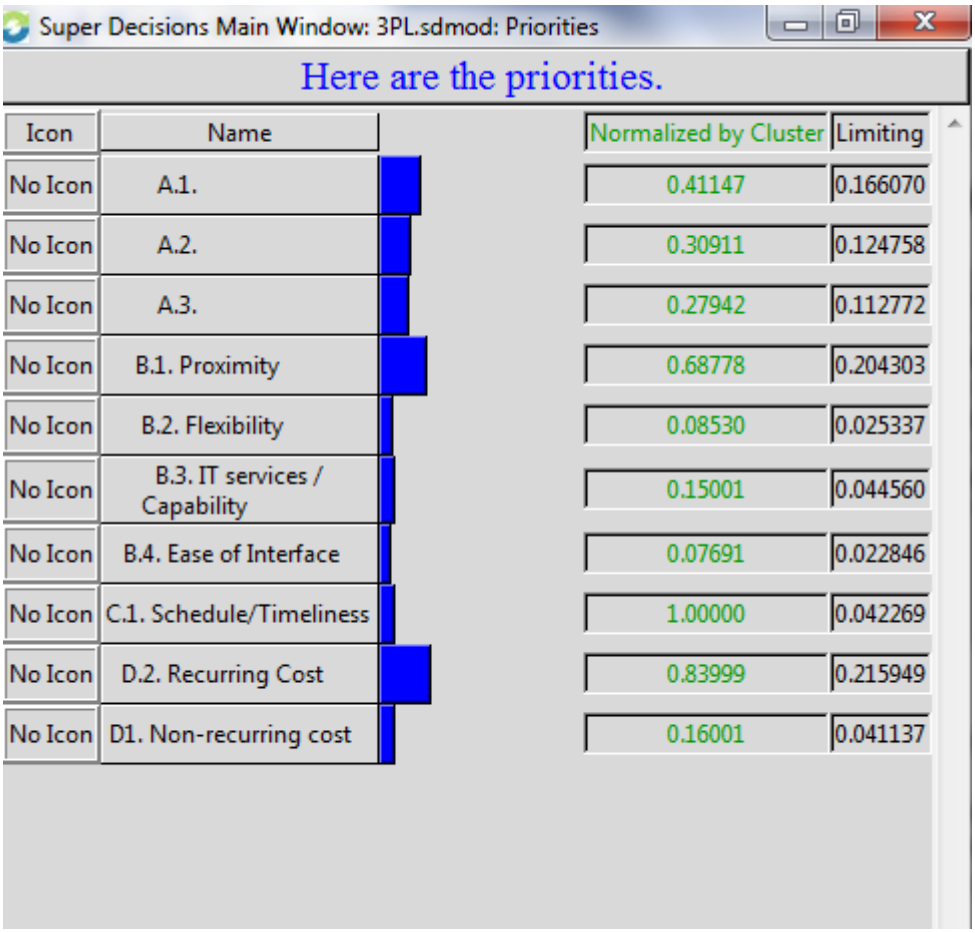

Figure 3. Priorities

A1 is the most preferable 3PL supplier followed by A2; recurring cost is the most influential factor followed by proximity. Flexibility is one of the least influential factors, together with ease of interface.
This model is descriptive as well as prescriptive.

6. Limitations

We had only one decision maker in our study, whereas, in some organizations, 3PL provider selection can be a group decision making process.

7. Conclusions

In conclusion, the research proposed a solution for solving interdependent logistics service provider selection problem for an aerospace company, as well as serves as a useful reference in logistics service provider selection problems.

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ANALYTICAL NETWORK PROCESS (ANP): METHOD FOR HELPING MANAGERS LEARN, IMPROVE FIRM CAPABILITIES AND GAIN A COMPETITIVE ADVANTAGE

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ABSTRACT

A key challenge for managers is to consistently develop firm capabilities. Learning and knowledge sharing required for capability development is facilitated through co-operation with participants of the supply chain system of a firm. However, a key challenge for managers is to identify and prioritize capabilities that are most likely to provide competitive advantage. Scholars have traditionally used Ordinary Least Squares (OLS) to understand the relationship between capabilities and firm performance. However, OLS is limited in its limited to explain the interdependences and connectedness amongst multiple firm capabilities themselves which is possible with ANP modelling. Thus we propose integration of OLS and ANP methods in explaining interdependences amongst firm capabilities and their effect on firm performance. However, we also caution against the cognitive bias limitations inherent to the ANP model.

Keywords: Supply Networks, Analytical Network Process, Ordinary Least Squares, Firm Capabilities

1. Introduction

There are two fundamental goals of management research. The first goal is to understand how management actions influence firm performance, such as understanding how a firm's performance would be influenced if the firm established cooperative relationships with its suppliers and customers. The second goal is to prescribe solutions to firm problems. This requires managers to prioritize possible solutions to problems and select the best alternatives to solve those firm problems. Typically many more value creating projects are proposed to solve firm problems than are feasible to implement. Most firms lack the resources to implement all value creating projects, so it is necessary to prioritize these projects and choose the one that will produce the highest value for the firm.

To achieve the first goal of management research, that is to understand how management actions influence firm performance, management scholars rely on statistical methods such as Ordinary Least Squares (OLS) to support a predicted relationship between an independent and a dependent variable. A generic OLS model is depicted below:

$$Y= \beta_0+ \beta_1 X+ \varepsilon$$

A given coefficient of the independent variable (β1) represents the strength of the relationship between the dependent variable (Y) and the independent variable (X). Although OLS can be employed efficiently to test a theorized relationship, its use to firm managers is limited because it does not help them to achieve the second goal of management research. OLS cannot be used to prioritize projects or to choose those that will create the most value for the firm. When a firm manager is faced with multiple value creating alternatives or projects, firm performance is likely to depend on the manager's ability to select a project that he or she believes will create the most value for the firm (Wang, Su, Tsai, & Lin, 2013). A manager's ability to determine which alternative to implement is important because the performance of a given firm is dependent on the application of an appropriate alternative to a given firm problem (Cyert & March, 1992). Another limitation of linear statistical methods is that it is very difficult to account for the feedback effect of Y on X. The feedback effect happens when a dependent variable influences an independent variable. For example, in the context of supply chain management, an improvement in firm performance (dependent variable) can lead to more cooperation with suppliers (independent variable). In sum, since OLS cannot help managers to prioritize alternatives, implement the alternative in an appropriate manner or account for the feedback effect of Y on X, linear statistical systems alone have limited use in management practice.

Firm managers can overcome these limitations of OLS by using the Analytic Network Process. The Analytic Network Process (ANP) is an approach to decision making that uses rationality and firm managers' intuition to select the best alternative or project from a set of known alternatives or projects (Saaty, 2004). Firm managers evaluate all known alternatives or projects with respect to some constant criteria (control criterion) and prioritize the alternatives using the pairwise comparisons. Comparisons between the given two alternatives are carried out using judgments of experts such as a firm manager's feelings, experience and intuition (Saaty & Vargas, 2012). Managers use their judgments to understand how alternatives interact with each other (inner dependencies) and how to account for independent variables and a dependent variable (outer dependencies). Since managers have to be cognizant of the inner dependencies when making decisions and ANP accounts for both inner and outer dependencies, ANP makes a useful management tool. For example, ANP can be employed when selecting suppliers (Gencer & Gürpinar, 2007) and selecting knowledge management strategies (Wu & Lee, 2007). Although ANP can be a powerful method that managers can use in their decision making process, it also has some limitations. ANP relies exclusively on expert judgment; therefore the results obtained are subject to firm managers' cognitive limitations and psychological biases. In some cases, experts might be inherently optimistic, in other cases inherently pessimistic and, yet in other cases, inherently overconfident (McKay & Meyer 2000). Such cognitive limitations can produce biased results, thereby prompting a firm to implement a sub-optimal alternative to a given problem which leads to sub-optimal organizational performance.

Given that both OLS and ANP have strengths and limitations; the primary purpose of this paper is to alleviate the limitations of each method by integrating elements of the OLS and ANP methods. In particular, we integrate OLS and ANP using regression coefficients obtained from OLS as inputs for ANP. We argue that integration of OLS and ANP help managers prioritize alternatives and select a project that creates the most firm value.

2. Literature Review

Supply networks are defined as networks of buyers and suppliers that exchange raw materials and information required to transform inputs into outputs through cooperation, rather than through arms-length market exchange. One of the crucial elements of cooperative supply chain relationships is learning (Dyer & Hatch, 2004). The knowledge acquired by engaging in learning activities with suppliers and buyers can be deployed to improve a firm's manufacturing capabilities such as low cost, quality, operational flexibility and delivery capabilities. Although these four manufacturing capabilities are essential to compete effectively in the marketplace, firms face trade-offs when developing these capabilities (Porter, 1996). Although a firm cannot develop multiple capabilities simultaneously, it can accumulate all four capabilities sequentially over time (Ferdows & De Meyer, 1990). It is also important to note that the development of one capability can influence the development of a different capability. For example, a firm that has developed its quality capability will also see improvements in its cost capability (Deming, 1986), because a reduction in product defects is directly related to a reduction in production costs. Given that there are dependencies among various manufacturing capabilities (inner dependencies) and firms face trade-offs when developing these capabilities, managers might have difficulty when determining which capabilities to develop first. In terms of ANP, learning from customers and learning from suppliers are two alternate ways to gain knowledge required to improve a firm's capabilities. In addition, a firm's decision about whether to learn from either suppliers or buyers, or both is determined the firm's need to develop a given capability required to compete in the market place. Therefore, according to ANP, manufacturing capabilities are considered criteria. In a firm, some capabilities have a higher impact on firm performance than others. Therefore, managers have to choose between learning from customers and learning from suppliers in the short run. They also must decide which capabilities to develop first that will produce the highest value for the firm. We argue that ANP is a method that can be used to prioritize the development of manufacturing capabilities.

3. Hypotheses/Objectives

As noted above, the primary purpose of our study is to integrate elements of OLS with ANP and to determine if the integration of these two statistical methods will enable managers to prioritize known alternatives and projects. We achieve this purpose by using supply chains as the context for our study.

4. Research Design/Methodology

The primary goal of this paper to understand how cooperative supply network relationships influence a firm's internal operational capabilities and subsequently operational capabilities influence firm performance. We can capture independent effects of cooperative relationships with a firm's suppliers and customers using the following OLS mediation models:

Mediating variables as dependent variables (IV → MV)

Eq. 1 Process-Efficiency Capability $= \alpha 1 + \beta 1 \text{Controls} + \beta 2 \text{Customer Learning} + \varepsilon 1$

Eq. 2 Process-Quality Capability $= \alpha 1 + \beta 1 \text{Controls} + \beta 2 \text{Customer Learning} + \varepsilon 1$

Eq. 3 Operational Flexibility Capability $= \alpha 1 + \beta 1 \text{Controls} + \beta 2 \text{Customer Learning} + \varepsilon 1$

Overall Firm Performance as a dependent variable (MV → DV)

Eq. 4 Overall Firm performance = α1 + γ1Controls + γ2Customer Learning + γ4Process-Efficiency Capability +ε1

Eq. 5 Overall Firm performance = α1 + γ1Controls + γ2Customer Learning + γ4Process-Quality Capability +ε1

Eq. 6 Overall Firm performance = α1 + γ1Controls + γ2Customer Learning + γ4 Operational Flexibility Capability + ε1

5. Data/Model Analysis

OLS results presented in Tables 1a shows that both learning from suppliers and customers influences all three capabilities.

Table 1a: OLS Estimations For Learning and Manufacturing Capabilities.

	Cost	**Quality**	**Flexibility**	**Delivery**
Constant	3.590***	2.467***	1.535	1.233
Interfirm Coordination	0.188***	0.069	0.192***	0.188**
Employees	0.014	0.002	-0.001	0.11
Job Title	***	-	-	-
Customer Learning	**0.140****	**0.259*****	**0.245*****	**0.211*****
Supplier Learning	**0.220****	**0.254*****	**0.212*****	**0.241*****
n	220	220	220	220
Chi-sq	74.74***	67.68***	72.37***	68.01***

Table 1b. OLS Estimation For Capabilities And Performance

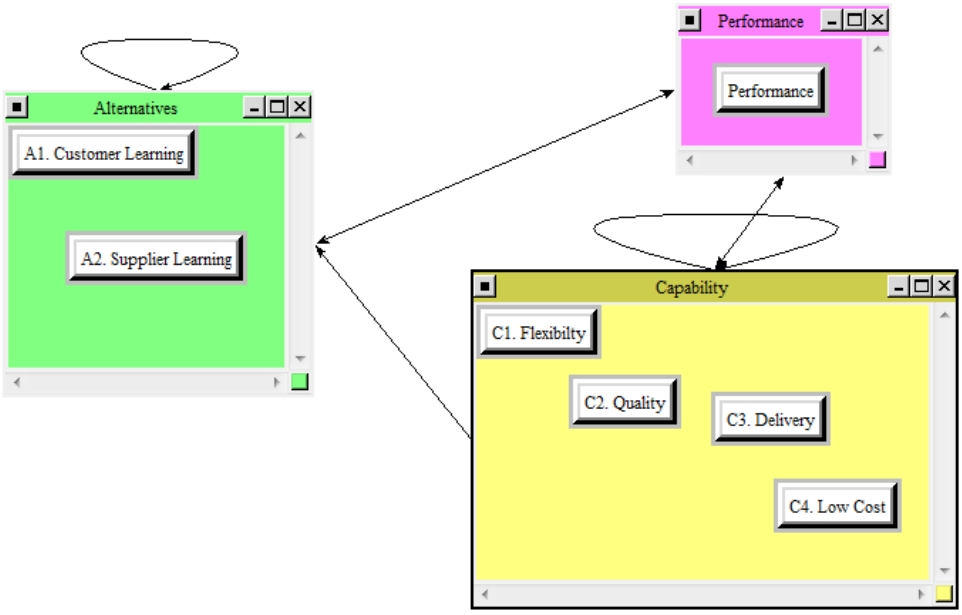
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Constant	2.274	1.443	0.548	0.366	1.245	0.012
Interfirm Coordination	0.168	0.081	0.034	0.051	0.056	0.041
Employees	-0.021	-0.022	-0.025	-0.023	-0.022	-0.025
Job Title	-	**	**	**	**	**
Learning		0.260***	0.205**	0.149+	0.232**	0.141
Cost			0.249***			0.152
Delivery					0.156	0.122
Quality				0.436***		0.416**
Flexibility					0.13	-0.094
R-sq	0.21	0.25	0.29	0.34	0.35	0.35
F-Value	1.43+	1.75**	2.03***	2.54***	2.48**	2.48***
n	220	220	220	220	220	220
Chi-sq						

Based on the OLS results presented in Table 1, one can conclude that a firm needs to learn equally and simultaneously from both suppliers and buyers. However, Table 2

shows that not all manufacturing capabilities lead to improvements in firm performance. We find that only quality capability significantly influence firm performance. Based on OLS results presented in these two tables, we can conclude that learning from suppliers and buyers influence firm performance only by influencing quality capability.

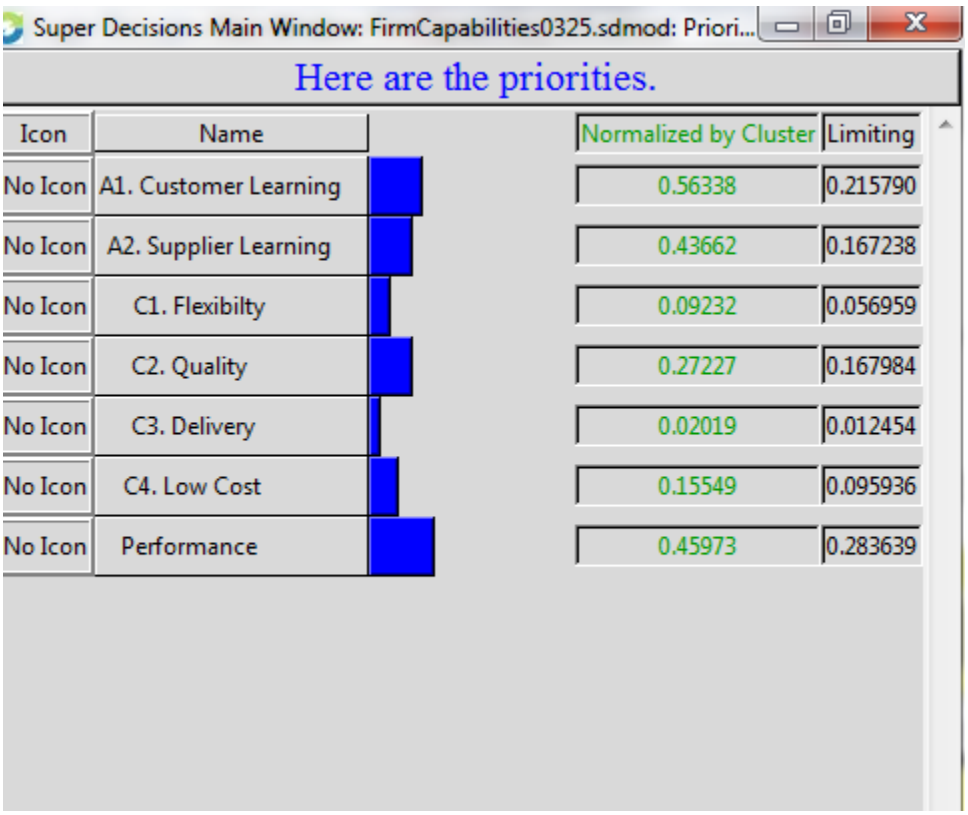
However, theoretically we know that firm needs to develop more than one manufacturing capability to compete effectively in the market place. Therefore, even though a firm cannot develop all three capabilities simultaneously, it needs to develop them simultaneously. Therefore, a firm needs to prioritize whether capability development process and develop these capabilities sequentially. Also, a firm managers need to take both inner and outer dependencies to understand in which order a firm needs to develop different manufacturing capability. To achieve this we use ANP and obtain a different result. We use regression coefficients obtained from OLS regressions to determine which alternative (learning from customers or learning from suppliers) are important to develop a given manufacturing capability. In a similar manner, we use the OLS coefficients to determine which manufacturing capability influences the firm performance the most (See Figure 1 and Table 2).

Figure 1. ANP model



ANP model is given in figure 1. From the model if we select a factor we can see the other factors influencing this particular factor. For example figure 2 illustrates that Quality capability influenced by performance, flexibility and cost, as well as the customer and supplier learning.

Table 2. Overall priorities.



According to Table 2, learning from buyers (customers) is more important compared to learning from suppliers. Therefore, a firm needs to devote more resources to acquire customer knowledge. Similarly, a firm needs to develop manufacturing capabilities in the following order quality, cost, flexibility and delivery.

In sum, we can integrate OLS and ANP to obtain unbiased results and determine the order in which a firm needs to develop different manufacturing capabilities and to determine whether to learning from buyer or suppliers to acquire knowledge essential to develop these capabilities.

6. Implication of our study to researchers and managers

One of the fundamental elements of applied research like management research is that it has not only the power to predict relationship between given firm actions and outcomes, but it also has prescpritive power. Research theories that can predict a relationship between actions and outcomes in isolation have little value, unless those theories conform to reality (Knight, 1921). Management researchers who have developed numerous management theories and empirical works have found support for those theories in isolation. For example, existing research in supply chain predicts a positive realtionship between cooperative realtionships and firm performance. The logic behind this predicted relationship is that

cooperative realtionships help firms develop their internal capabilities, which in turn influece firm performance. Although the existing empirical research on this topic has found support for the theorized relationship, this research dos not help managers to determine which capabilities to develop first using knolwedge acquired by engaging in learning activities with suppliers and buyers. This shortcoming of existing literaure is due to the fact that OLS cannot be used to prioritize different alternatives. Therefore, by integrating OLS and ANP, our research will enhance the prescriptive power of the existing research on supply chain management.

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AHP/ANP FOR SUSTAINABLE SUPPLY NETWORKS

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ABSTRACT

The aim of this research is to summarize existing research on multiple criteria models for supply networks and find the state of the art of the AHP/ANP contributions towards sustainable supply networks. This provides insights for future research directions and needs.

Globalization places demands on supply network management beyond pure economic issues. Cost minimization, revenue, and profit maximization by themselves are not sufficient. For example, fair labor conditions, diversity, safety, and environmentally friendly product development (greener product design) and production (cleaner process technology) are also important. Competition is no longer among the companies; it is among the supply networks.

Based on our preliminary research we found that the environmental dimension still dominates, social aspects are widely ignored, and social criteria need further exploration. Also, among the multiple criteria methodologies used in sustainable supply chains, the AHP was most frequently used and recently, articles using ANP to manage sustainable supply chains are rising. We could not find any study using any multiple criteria approaches including the AHP and ANP in sustainable supply network management. We contend that this is a promising area for the AHP/ANP community.

Keywords: Literature Review, Sustainable Supply Networks, Analytic Network Process, Analytic Hierarchy Process, Multiple Criteria Decision Making

1. Introduction

Today's competitive, fast-moving business environment has irrevocably changed the supply chain and the management of its functions as we know it. The traditional "chain" of sourcing/production/distribution linked in a linear and simple fashion is no longer a reality given the complicated and global rate at which business is now conducted. Many industry experts have even created new jargon: it is no longer a "supply chain" but rather a "supply network." The new approach to supply chain management (SCM) means that companies must find a way to improve communication and information flow, thereby

converting the traditional supply chain into an adaptive and real-time supply network. The theory is that this will allow manufacturers to realize a holistic, responsive and flexible management of a network of supply chain resources that improve production and increase profitability.

Sustainable supply chains meet the needs of the present generation without compromising the ability of future generations to meet their own needs. There are three pillars of sustainability: Economic, Environmental, and Social. The Economic pillar is the most commonly addressed dimension. In addition, the environmental life cycle impacts are increasingly being studied. However, research is still dominated by green/environmental issues and the social aspects and integration of the three dimensions are still rare. During the last two decades, the focus on optimizing has moved from a specific facility or organization to the entire supply chain and later, on entire supply networks. Sustainability must also address issues and flows that extend beyond the core of supply chain management such as product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of life, and recovery processes at the end-of life.

Lately, there is an increasing awareness by organizations that sustainability and profitability are not mutually exclusive concepts. Their common perspective is that the sustainability creates long-term shareholder value, as it is an obligation for companies to meet the needs of their shareholders while sustaining the resources that will be needed in the future. Further, the scarcity of raw materials such as fossil fuels and water, new regulations of governments, and the global awareness about sustainability leads companies to develop sustainable strategies.

Sustainable Supply Network Management (SSNM) requires a multiple criteria approach, since it is inherently a multiple criteria problem. In addition, since certain criteria are quantitative while others are qualitative, the study of SSNM is very conducive to the AHP/ANP approach.

Initially, the difference between SCM and Supply Network Management (SNM) is explained and the concept of sustainability is defined. Different multiple criteria methodologies are briefly described, including the AHP/ANP. Since the paper is a literature review on multiple criteria approaches in SSNM, articles using multiple criteria decision making (MCDM) in sustainable supply chains are first summarized. Next, a data analysis is performed which includes the journals in which these articles appeared and a time distribution of the articles is given. For some articles, some content analyses are performed. Limitations of the research and future research directions are given in the conclusion.

2. **Literature Review**

Brandenburg et al. (2014) performed a content analysis of 134 carefully identified papers on quantitative, formal models that address sustainability aspects in the forward SC. They found that a great number of the publications and models appeared in a limited set of six journals, and most were analytically based with a focus on MCDM. The tools most often

used included the AHP and ANP, as well as life cycle analysis. Buyukozkan & Ciftci (2011) integrated incomplete preferences into ANP and applied the methodology in a sustainable supplier selection problem. They established and analyzed criteria using expert judgments, estimated missing values using incomplete preference relations, evaluated alternatives using fuzzy ANP, and identified the optimal solution.

Seuring's (2013) review of 308 papers found out that only 36 used quantitative models (Table 1). Most of these were Life-cycle assessment (LCA) based studies, followed by Equilibrium models. Seuring separated the AHP from other MCDM approaches and found that there were more AHP approaches used than any other MCDM methods in addressing sustainability and supply chain management.

Table 1. Methods Used in 36 Quantitative Articles

Modeling Approach	**Number of Papers**
Life-cycle assessment (LCA) based studies	11
Equilibrium models	9
Multi-criteria decision making (MCDM)	6
Analytical Hierarchy process (AHP)	8

3. Hypotheses/Objectives

The aim of this research is to summarize existing research on multiple criteria models for supply networks and find the state of the art of AHP/ANP contributions towards sustainable supply networks. This provides insights for future research directions and needs.

4. Research Design/Methodology

Our literature review is restricted to peer reviewed publications. We only included academic journals but excluded conference proceedings, books, master and doctoral theses. We reviewed articles published in the period from 2000 to 2014. We used the databases EBSCO and ABI/INFORM.

5. Data/Model Analysis

Figure 1 illustrates the time distribution of the articles reviewed by Seuring (2013). The majority of these articles were published in the Journal of Cleaner Production (9) and followed by Expert Systems with Applications (5). The European Journal of Operational Research (EJOR) had 4 and the International Journal of Production Economics (IJPE) and the International Journal of Production Research (IJPR) both had 3 articles. Others (Decision Support Systems, Management Research Review, Management Science, Computers in Industry, etc.) had only 1 article published on sustainability and supply chain management.

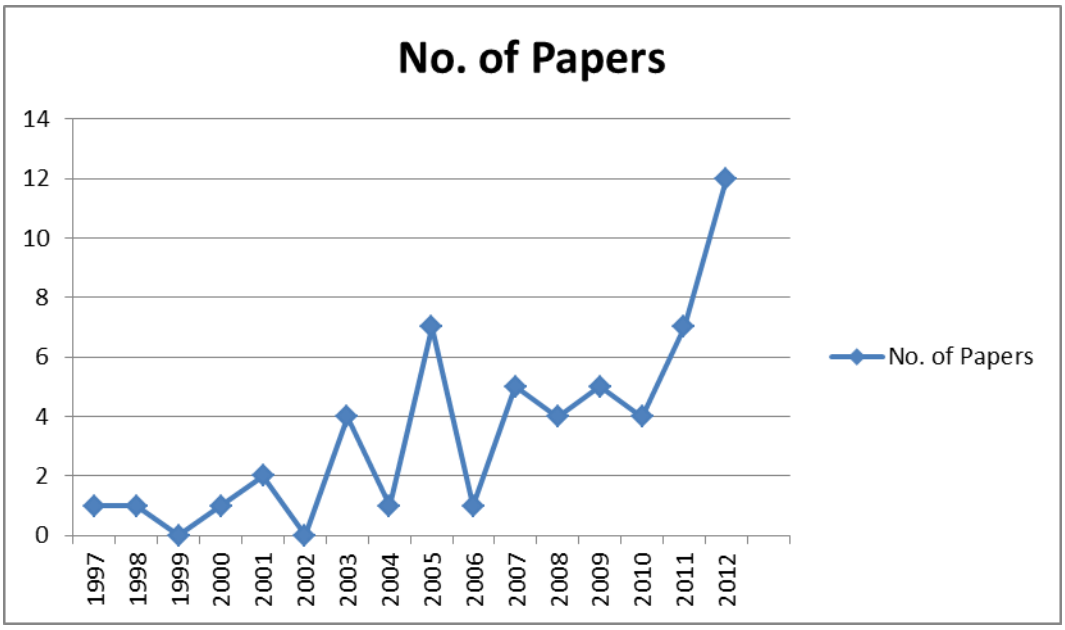

Figure 1. Time Distribution of the articles

6. Limitations

This is a research in progress. We hope we will have more concrete more comprehensive findings by symposium date.

7. Conclusions

We could not find any articles addressing sustainability and supply chain networks. We contend that this is a fertile area of research for AHP/ANP researchers. Most of the studies are case based. This is expected because we need to understand the problem in a real setting. This can be explained by the fact that the sustainability area is a relatively new research field and researchers need to do more case study work to understand the real issues and problems, something for which case study methodology is well-suited. This is in contrast to the trend in operations management research where case study research is not well utilized.

Based on the articles reviewed, the environmental dimension still dominates, social aspects are widely ignored, and social criteria need further exploration.

Among the MCDM methodologies used in SCM research, the AHP was used most frequently, and recently, there is an increase in the use of the ANP. We believe it is because of the AHP and ANP's ability to handle both quantitative and qualitative criteria.

8. Key References

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