Stakeholder Collaboration Modeling for Efficient Supply Chain Management

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Abstract

Stakeholder Collaboration Modeling for Efficient Supply Chain Management

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In response to current economic downturn coupled with intense global competition, concept of supply chain collaboration has emerged as a possible solution for firms aiming to gain competitive advantage through cost reduction, increased asset utilization and improving service levels.

In this research, we have analytically examined and identified the stages involved in facilitating supply chain collaboration between multiple retailers and/or suppliers in a supply chain network. The study considers three types of collaboration strategies and incorporates a combination of different techniques such as cluster analysis, analytical network process (ANP) and game theory that can help potential partners to plan and implement collaboration initiatives in the supply chains. The solution approach along with illustrative example involving a retailer and a supplier is presented which can serve as a guideline for potential firms contemplating about entering into collaboration. In order to help prospective partners make the decision regarding which type of collaboration will be beneficial for them, a collaboration decision making model is built using C++ language. The collaboration decision making model incorporates concept of Nash equilibrium to ensure each partner is making the best decision while taking into consideration the decisions of others. Pre-qualification screening of potential suppliers and/or retailers for possible collaboration is carried out by utilizing methods such as cluster analysis and analytical network process (ANP) while final partner selection is made through application of game theory. Finally, profit allocation mechanism based on Shapley method is presented which ensures profit is distributed according to the "adding value" each partner brings for the alliance.

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I dedicate this work to

my parents for their continuous

support and encouragement throughout

my life.

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List of Acronyms

ANP	Analytical Network Process
AHP	Analytical Hierarchical Process
CPFR	Collaborative Planning, Forecasting and Replenishment
CBR	Case Based Reasoning
DEA	Data Environment Analysis
EDI	Electronic Data Interchange
ESG	Environmental, social and corporate governance
FC	Full Collaboration
ISIN	International Securities Identification Number
MCDM	Multi-Criteria Decision Making Method
MOP	Multi-Objective Programming
NC	No Collaboration
PC	Partial Collaboration
POS	Point of Sale
VPA	Vendor Profile Analysis

Chapter 1:

Introduction

1.1. Background

Supply Chain Collaboration, as defined by Simatupang & Sridharan (2002), is an interaction between "two or more chain members working together to create a competitive advantage through sharing information, making joint decisions, and sharing benefits which result from greater profitability of satisfying end customer needs than acting alone." Current economic downturn, intense global competition and fast changing customer demands, have made it difficult for organizations to stay competitive in the current market place. Recession scarred customers are constantly looking for better quality and innovative products at a relatively low price. In the nutshell, organizations which are capable of selling products or services which satisfy the above mentioned specifications will be able to dominate the market.

In response to this challenge, the concept of supply chain collaboration has emerged as a new approach to attaining competitive advantage through cost reduction, increased asset utilization, reduced inventories, and shared business risk that arises as a result from the coordination of actual customer demand with supplier production plans (Lewis, 1990; Parker, 2000; Horvarth, 2001; Anderson & Lee, 1999; Tidd et al., 2002). Effective supply chain collaboration can help organizations reduce excess inventory, shorten lead times and increase sales and customer service levels (Anderson & Lee, 1999). Furthermore, supply chain collaboration has allowed organizations to enhance flexibility and capabilities by fostering relationships that increase skills and knowledge, facilitate easier product development, offer access to new technologies and reduce time to market (Lewis, 1990; Parker, 2000, Holton, 2001; Tidd et al., 2002).

While supply chain collaboration amongst independent firms can often provide them with competitive advantage, however, lack of awareness regarding the presence of barriers of collaboration might impede the benefits of collaboration (Ramesh et al., 2010). A number of factors such as the level of trust between collaborating partners (Delbufalo, 2012), willingness to share information (Barratt, 2004), mistrust regarding the fairness of benefit, costs and risk sharing (Cruijssen, 2012; Rossi, 2012) and availability of adequate measurement systems to support the efficiency and flexibility requirements of the supply chain (Reddy, 2001a; Karahannas & Jones, 1999) can influence the level of benefits that can be realized as a result of collaboration.

One important factor found to be critical in ensuring successful collaboration between partners is trust (Morgan & Hunt, 1994). Trust exists when partners have complete faith over each other's reliability and capabilities (Heikkila, 2002). The need for trust to exist between partners in collaboration has been recognized as a vital aspect of buyer- supplier relationships (Anderson & Narus, 1990). According to Dyer (1996), various research studies have shown that successful partnerships results when partners demonstrate a willingness to engage in long-term orientation or commitment.

According to Sheu & Chwen (2006), information sharing is seen as a key ingredient for ensuring successful collaboration. Several studies (Bowersox et al., 2000; Cannon & Perreault, 1999) have indicated that successful supply chain collaborations are linked with high levels of information sharing.

Adequate information technology (IT) capabilities and measurement systems can also be an important factor for collaborative partnerships (Sabath et al., 2001). Sriram & Banerjee (1994) are of the view that electronic data change (EDI) possibly can develop closer partnership between collaborative partners. Bowersox & Daugherty (1995) emphasize the importance of accuracy and timeliness as important factors for successful collaboration. High interdependence is another factor that motivates the partners' readiness to negotiate functional transfer, share key information and involve in joint operational planning (Handfield, 1993; Heikkila, 2002).

Keeping all these implementation concerns in view, this research will be looking at specific solutions which will not only be a complete guide for facilitating & implementing collaboration amongst the prospective partners but will also ensure that it remains effective for a long term.

1.2. Problem definition

The purpose of this thesis is to provide a framework and solution approach for facilitating collaboration amongst multiple retailers and/or suppliers for achieving more effective and economical supply chain. In order to achieve this aim, a number of research issues will be addressed in this thesis as shown below:

1. Identifying pre-qualification criteria for potential suppliers and/or retailers for possible collaboration.
2. Determining win-win collaboration situation for multiple retailers and/or suppliers under different scenarios.
3. Collaboration model development & simulation of different collaborative strategies.
4. Profit allocation mechanism amongst multiple retailers and/or suppliers post collaboration.

The first research problem covers identification of pre-qualification criteria of potential suppliers and/or retailers for possible collaboration. Initially, cluster analysis is performed for grouping retailers and/or suppliers into clusters of interest. This significantly reduces the number of retailers and/or suppliers by grouping only those ones which share similar characteristics such as location or industry type. The next step involves application of Analytic Network Process (ANP) technique for solving multi-criteria collaboration partner selection problem by taking into account the interdependencies between different criteria.

The second research problem applies game theory concept for analyzing the likely behavior of the retailers and/or suppliers under different collaboration scenarios. Three possible modes i.e. full collaboration, partial collaboration, or no collaboration are discussed. Payoff functions for each partner at different modes are developed and then Nash equilibrium analysis is carried out to determine the win-win situation for each of the partners involved in the game by taking into consideration the decisions of all the players.

In the third research problem, a collaboration model is developed by incorporating the concept of Nash equilibrium. The model is built using C++ language. The model takes the following costs as inputs:

S_{xx} = system implementation and integration cost

O_{xx} = operational cost

P_{xx} = partnership instability cost

T_{xx}= switching cost

where subscript xx denotes the costs for each partner under one of the three collaboration modes.

These costs can differ under various modes i.e. full collaboration, partial collaboration and no collaboration. The model actually sums up and compares these costs for each partner under different collaboration modes and then suggests the best course of action for each partner. The main aim of the model is to depict the likely behavior of the players under different scenarios. For instance, the players would always go for a particular type of collaboration where there are lowest costs involved i.e. high payoff functions.

In the fourth research problem, profit allocation mechanism amongst retailers and/or suppliers is developed through utilization of cooperative game theory to ensure equal profit and risk allocation amongst the partners.

1.3 Research scope and limitations

The scope of the thesis is to identify and research all the necessary stages involved in managing the lifecycle of a supply chain collaboration process from its conception through planning and implementation, to successful execution and disposal. Specifically, the scope of the thesis is to provide comprehensive guidelines and solution approach for facilitating collaboration amongst multiple retailers and/or suppliers for achieving economic supply chain. A solution approach is provided which covers all the aspects involved in the lifecycle of a typical supply chain collaboration process.

The study has some limitations. A possible limitation of this study is that it provides framework and solution approach for facilitating collaboration from only retailer and supplier industry's point of view. Efforts were made to contact some of the world's leading retailers and suppliers, currently collaborating with each other, to ascertain their initial approach towards going into collaboration but they were unwilling to share the information. However, persistent effort by the author allowed him to access some useful information from Concordia University's library resources which helped him to envisage the likely approach of a typical retailer or a supplier before going in collaboration.

This study considers only three types of collaboration possibilities which can exist between multiple retailers and/or suppliers. These include full collaboration, partial collaboration and no collaboration. Cluster analysis is performed by keeping into account only three factors i.e. location, industry type, market capitalization. The collaboration model takes only total switching costs into account before suggesting the best course of action. The input costs used for the collaboration model are fictional numbers and do not represent real life data.

1.4. Thesis outline

The thesis comprises of five chapters. Chapter 1 covers the background, purpose and the structure of the thesis. In Chapter 2, a literature review on collaboration planning in supply chain is presented along with driving forces, barriers and effects. Chapter 3 provides solution approach for facilitating collaboration amongst multiple retailers and/or suppliers for achieving more effective and economical supply chain. In Chapter 4, numerical application of solution approach is presented. Finally, in chapter 5, conclusions along with future works and contributions of the present study are presented.

Chapter 2:

Literature Review

The literature review in this thesis can be divided into four main parts; the first part deals with the term “Supply Chain Collaboration”. It concisely provides recent history of the supply chain collaboration and briefly discusses the motivation, types, models and the outcomes of the supply chain collaboration. The second part consists of the driving forces, barriers and the enablers of supply chain collaboration. The main reasons for studying the literature in this part are to identify the bottlenecks involved in the process of collaboration and to develop a solution approach which keeps these drawbacks into consideration. In the third part, the process of “supply chain collaboration” is explained. This part discusses all the steps involved in supply chain collaboration process from its conception to planning and implementation. The main aim of this section is to provide the foundation for the stakeholder collaboration modeling process and hypothesis assessed in this thesis. The fourth part will summarize the literature review and will identify the current gaps related to the process of supply chain collaboration.

2.1 Collaboration in supply chain defined

Cao & Zhang (2010) define supply chain collaboration as “a partnership process where two or more autonomous firms work closely to plan and execute supply chain operations towards common goals and mutual benefits”. Horvath & Kumar (2006) define collaboration as an interaction between “two or more chain members that focus on joint planning, resource coordination, and process integration between buyers, suppliers, and other partners in a supply chain. Owing to today's economic downturn coupled with rapidly changing customer needs and technologies, there has been an increased emphasis on supply chain collaboration.

Collaborative supply chain management moves beyond the concept of mere transactions exchanges and entails tactical joint decision making mechanism among the partners in the areas of collaborative planning, forecasting, distribution and product design (Kumar, 2001).

2.1.1 The motivation for supply chain collaboration

The motivation for organizations to pursue supply chain collaboration comes from the fact that collaboration in general can help firms to share risks, access complementary resources reduce inventories and transaction costs and enhance profit performance and competitive advantage over time (Mentzer et al., 2000).

According to research undertaken on collaborative practices by team from Neeley School of Business at Texas Christian University, successful collaboration encourages participants not only to share information openly and freely but also to communicate in an honest truthful way, which in turn, improves the quality of relationship between collaboration partners.

Under current business climate, it is difficult for firms to do business on their own and not to enter into collaboration. As a consequence of economic downturn coupled with increased globalization, businesses have become more specialized and time to market has become one of the most critical aspects of competitiveness in today's volatile business environment. Since collaboration provides firms with an opportunity to enter into a partnership where they would be able to exploit each other's competencies and combine them in order to fulfill customer requirements quickly, this has resulted in more and more companies to enter into collaboration so that competitive advantage over the rivals can be gained.

According to Sandberg (2005), true essence of supply chain management is that firms in a supply chain should work together to establish collaborative atmosphere where mutual trust, sharing of risks, and rewards and extensive information sharing should counteract sub optimizations in the supply chain. In other words, effective supply chain requires firms to constitute a kind of relationship where each one in the chain agrees on standardized solutions and commits to mutually agreed goals and objectives. It becomes imperative for every firm to focus on the chain optimization instead of individual gains.

2.1.2 Outcomes of supply chain collaboration

Collaboration has been considered to be an influential factor behind effective supply chain management (Ellram et al., 1990). Collaborative relationships can help firms to share risks and exploit each other's complementary resources (Park et al., 2004*).* The outcomes of successful collaboration include cost reductions, increased revenues, and enhanced operational flexibility to manage with high demand uncertainties (Lee et al., 1997). Supply chain collaboration initiatives concentrate on lowering uncertainty across the supply chain, which in turn, lessen bullwhip effect and results in reduced inventory costs and faster time to market (Lee et al., 1997).

Collaborative partnerships also result in increased economies of scale and risk (Kumar & Dissel,1996). Effective supply chain collaboration can help firms to eliminate excess inventories, increase sales, reduce lead times and improve customer service levels (Anderson & Lee, 1999).

According to McLaren et al. (2002), several surveys and studies have indicated that projected benefits of supply chain collaboration fall into two main categories namely cost reduction and increased responsiveness. Cost reduction category includes benefits such as reduced inventory levels, product costs and process costs that originate as a result of better coordination of actual customer demand with supplier production plans. Increased responsiveness category includes advantages such as faster product to market cycle times, enhanced service levels, and a better understanding of customer needs across the entire supply chain owing to market intelligence and demand visibility (Mentzer et al., 2000).

2.2 Forms of collaboration

According to Barrat (2004), there are different forms of potential supply chain collaborations which can be divided into two main categories, vertical and horizontal collaboration. Furthermore, Langley et al. (2008) expresses third form of collaboration called "Full Collaboration", where it syndicates the capabilities of both the vertical and horizontal collaboration. Brief description of the above mentioned forms of collaboration are as follows:

2.2.1 Vertical collaboration

Vertical collaboration usually takes place between buyers and sellers in a supply chain (Langley et al., 2008). In vertical collaboration, two or more firms such as manufacturer, retailers, distributors and parts and materials suppliers enter into an agreement to share their resources, responsibilities, and performance information to provide services to relatively similar end customers (Simatupang & Sridharan, 2002). Vertical collaboration results in better physical and information flows, improved inventory management control and enhanced transportation systems

(Caputo & Mininno, 1996). Some examples of vertical collaboration include vendor managed inventory (VMI), and collaborative planning, forecasting and replenishment (CPFR) (Blecker et al., 2010).

2.2.2 Horizontal collaboration

Horizontal collaboration refers to a situation where two or more unrelated or rival firms engaged in producing similar products or different parts of one product, decides to engage in a in a cooperative relationship so that resources such as warehouse space and manufacturing capacity can be shared (Simatupang & Sridharan, 2002). According to Langley et al. (2008), horizontal collaboration can help participating members to identify and eliminate the hidden costs in the supply chain which everyone pays for through facilitation of joint product design, manufacturing, sourcing and logistics. Horizontal collaboration can help firms to reduce logistics and administration costs and to improve procurement terms owing to group purchasing power (Soosay et al., 2008). Horizontal collaboration also helps to overcome financial barriers to trade (Manning and Baines, 2004). An example of horizontal collaboration is “Group Purchasing” in which competitors cooperate with each other to buy goods so that volume discounts can be gained from the common seller (Ozener, 2011).

2.2.3 Full collaboration

Full collaboration is basically the combination of both vertical and horizontal collaboration so that more flexibility can be gained (Langley et al., 2008). According to Mangan et al. (2008), combination of horizontal and vertical collaboration can help in reduction of inventory carrying costs, unproductive waiting time, overall transport costs and can enhance lead time operation through incorporation of collaborative methods such as joint planning and technology sharing. Examples of full collaboration includes Nistevo, Lean Logistics, and Transport Dynamics which tries to coordinate shippers and carriers of multiple-businesses in an effective transportation network (Simatupang & Sridharan, 2002).

The three forms of collaboration as defined by Barrat (2004) and Langley et al. (2008) can be summarized as shown in figure 1 below:

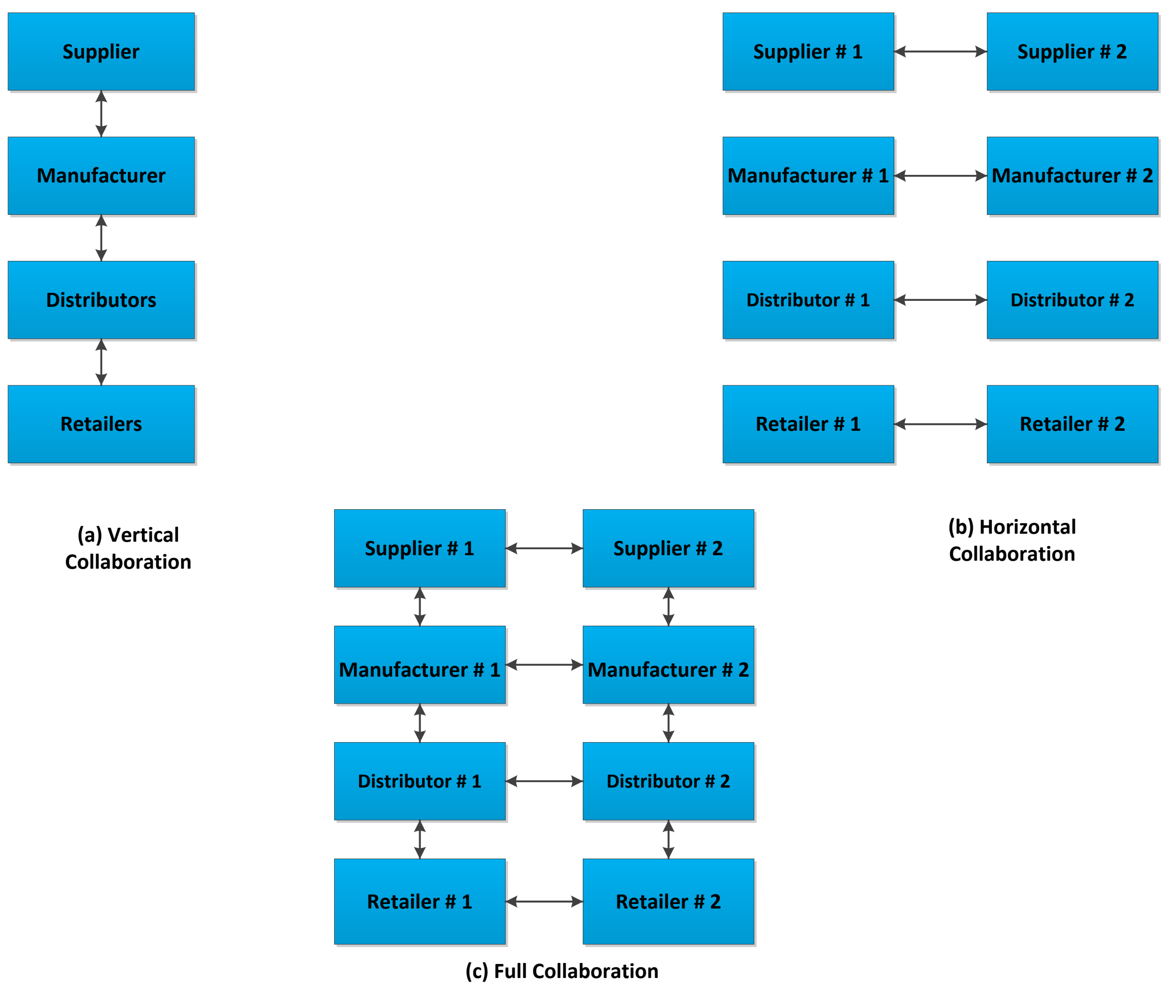

Figure 1: Form of Supply Chain Collaborations (Source: Langley et al., 2008)

2.3 Types of collaboration

There are various types of supply chain collaboration. Some of the most common ones include strategic alliances, joint ventures and cooperative arrangements (Soosay et al., 2008). Brief descriptions are as follows:

2.3.1 Strategic alliances

Strategic alliances are generally considered as a particular form of inter-firm relationships that are supposed to be of long term and in which two or more partners share resources, costs, knowledge, risks and capabilities with the aim of improving the competitive position of each partner (Spekman & Sawhney, 1990). According to Lorange & Roos (1991), strategic alliances can help partners to quickly get access to new technologies, enter new markets, evade strict governmental controls and to promptly acquire knowledge from industry's leaders. Strategic alliance provides each partner with an opportunity to focus on their core competencies which gives them competitive advantage over their rivals.

2.3.2 Joint ventures

Join ventures is basically a formal agreement between two or more firms in order to create new products and services, enter new and foreign markets, or possibly both (Beamish, 2008). Joint ventures help to create new market opportunities in which the firm, searching for a new market usually provides goods or services, marketing strategies and financial capability whereas local party provides market knowledge, labour and access to public and private sector networks (Collins & Doorley, 1991). According to Hennart (1988), firms enter into this type of agreement to facilitate collaboration at a single point in the supply chain so that economies of scale in manufacturing or distribution can be realized.

2.3.3 Cooperative arrangements

Owing to rapidly changing technologies and increased globalization, many organizations are forced to look for cooperative arrangements with other firms (Ring & Ven, 1992). According to Kumar (1996), the main purpose of cooperative efforts is to move from purely contractual arrangements to somewhat more trusting relationships with parties. This move urges the parties such as manufacturers and suppliers to start relying on each other to be supportive and build trust by taking into consideration a long term view of the relationships and dealing productively with the potential conflicts that might arise (Hines, 1995).

2.4 The supply chain collaborative planning

Few studies have identified the important steps involved in achieving supply chain collaboration (Lummus et al., 1998; Corbett et al., 1999; Boddy et al., 2000). These steps raise some vital points regarding the role of planning in supply chain collaboration (Cassivi, 2006). According to VICS association, a more comprehensive approach known as collaborative planning, forecasting and replenishment (CPFR), presents a chronological method that identifies key actions to be carried during the formulation of collaboration initiatives.

CPFR is basically an initiative of the voluntary inter-industry commerce standards association (VICS), which outlines the operational actions that facilitate partners to plan collaboration initiatives in the supply chains (VICS, 1998). CPFR has its roots in a series of tactics implemented in the 1980’s and 1990’s to optimize activities related to inventory and replenishment (Cassivi, 2006). These methods were aimed for bringing supply chain partners close to each other but none of them actually laid stress of information sharing between partners (Boddy et al., 2000). Collaborative planning, forecasting and replenishment (CPFR) incorporates the operational benefits of all these methods and combines collaborative mechanisms to enable information sharing exchange in a multi-layered supply chain (Boddy et al., 2000). As can be seen in the figure 2 below, the four collaborative activities are divided into 8 tasks - two for each collaborative activity (Cassivi, 2006).

Collaborative activities	Collaboration tasks
Strategy and Planning	1. Collaboration Arrangement 2. Joint Business Plan
Demand and Supply Chain Management	3. Sales Forecasting 4. Order Planning/Forecasting
Execution	5. Order Generation 6. Order Fulfillment
Analysis	7. Exception Management 8. Performance Assessment

Figure 2: Collaborative Planning Process (Source: Cassivi, 2006)

Strategy and planning

The first stage of strategy and planning entails two critical steps: collaboration arrangement and joint business plan. The subsequent stage involves two forecast related steps: Sales forecasting and order planning/forecasting. The next stages: execution and analysis comprises two steps each i.e. order generation and order fulfilment for execution stage and exception management and performance assessment for analysis stage. In CPFR process, planning stage is crucial since this is the stage where partners form collaboration initiatives and terms. While planning supply chain relationships, first two steps in CPFR approach are significant. During collaboration arrangement, all partners' needs and goals are simplified. Particpating firms devise and consent on a collaborative program which ascertains vital supply chain metrics. This arrangement ensures adequate commitment to collaboration by all supply chain partners and brings together all parties concerned around the goals (Cassivi, 2006). The second step i.e. joint business plan allows partners to penetrate collaboration process through the product/service information to be exchanged. This requires the swap of strategies along with the business plans between partners with the aim of collaborating on the formation of a joint business plan. Organisations mostly communicate about continuing business tactics and then incorporate the features of the joint business plan into their planning systems (Cassivi, 2006).

Demand and supply management

In the demand and supply change management stage, sales forecasting task involves forecasting the consumer demand which is then used to develop an order planning/ forecasting schedule in which inventory lead times, logistics restrictions and other important factors influencing the planning are identified (Cassivi, 2006).

Execution

In execution stage, order generation is used to convert forecasts to exact demand so that order fulfillment task can be initiated which is actually the process of producing, dispatching and keeping the goods (Cassivi, 2006).

Analysis

Lastly, in the analysis stage, two tasks, i.e. exception management and performance assessment are used to continuously observe any abrupt variations in quality and to offer the important metrics to assess the success of the business objectives and to examine the industry trends which can help in changing the strategy more rapidly if required (Cassivi, 2006).

The advantages of CPFR include improved customer service (Cassivi, 2006), cost reduction by removing the middle man amongst others (Pallab, 2012), early involvement of partners (Cassivi, 2006), more sales (Pallab, 2012) and benefits from a pull process (Cassivi, 2006).

2.5 Supply chain collaboration model

Since the essence of collaboration is to optimize profitability, the chain members are required to plan, implement and control vital decisions at the interface boundaries which are related to specifying and providing products/services to end customer that result in mutual advantage (Simatupang & Sridharan, 2004). The collaborative supply chain presumes that the chain members synchronize decision making across supply chain, share information to make efficient decisions that helps enhance performance and incorporate incentive tactics for specifying decision bonus and penalty mechanisms (Lee et al., 1997; Simatupang & Sridharan 2002). As a result of that, the model of supply chain collaboration can be classified by three enabling elements of collaborative practice which includes information sharing, decision synchronization and incentive alignment (Simatupang & Sridharan, 2004). These three elements of collaborative practice are supposed to assist the chain members in cross organizational cooperation that facilitates them to achieve enhanced overall performance.

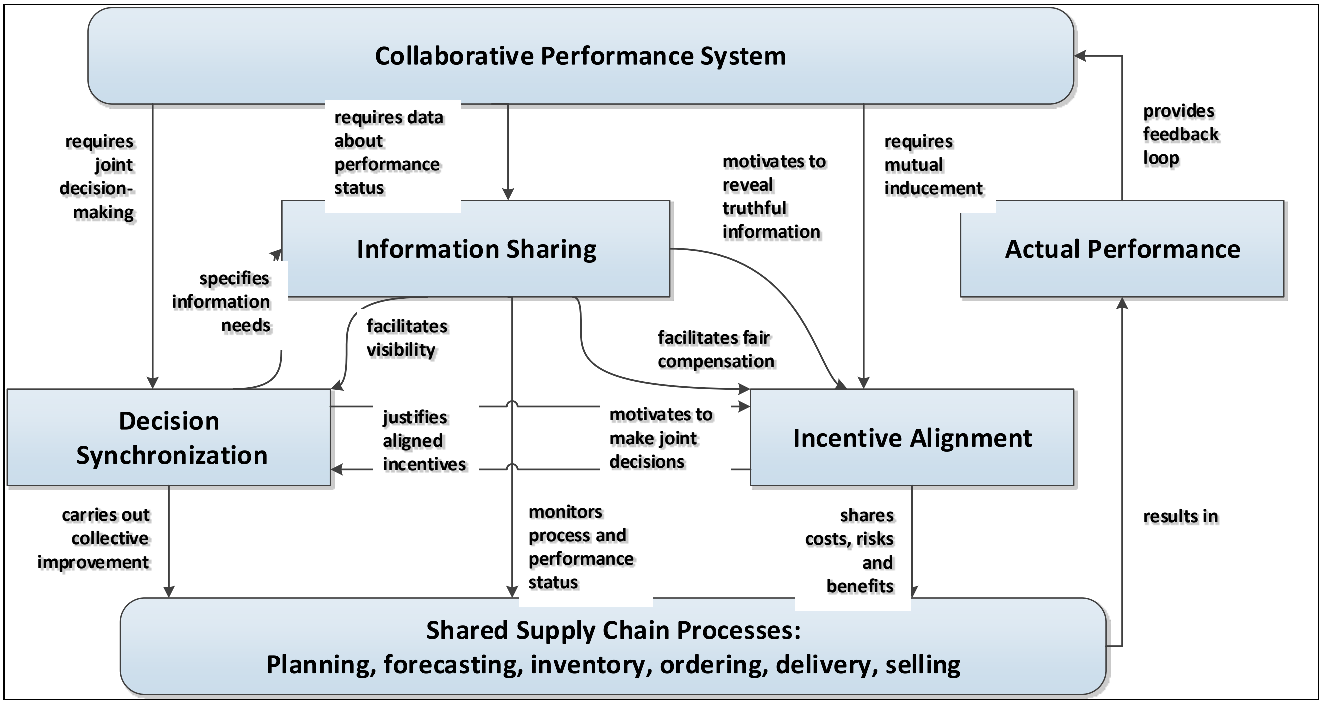

Figure 3: A Conceptual Model for Supply Chain Collaboration
(Source: Simatupang and Sridharan, 2004)

As can be seen in figure 3, the three elements of supply chain collaboration are linked directly to supply chain performance (Simatupang & Sridharan, 2004). The details of the three elements of supply chain collaboration are as follows:

2.5.1 Information sharing

Information sharing is the initial point in any supply chain collaboration. The purpose of information sharing is to obtain and circulate timely and useful information to allow decision makers to plan and manage supply chain operations (Cassivi, 2006). Effective information sharing delivers a shared basis for joint actions by different functions across interdependent firms (Whipple et al., 2002). Some examples of shared data include points of sale (POS) data, inventory levels, demand forecasts, inventory costs and delivery schedules. Information sharing also helps in facilitating clarity about demand, common performance and fulfillment process (Pallab, 2012). Fisher (1997) is of the opinion that supply chain collaboration results in cohesive market focus, better coordination of demand fulfillment and sales and minimum risks related with demand uncertainty. Therefore, information sharing seems to allow the chain members to perform better (Lee et al., 1997; Whipple et al., 2002).

2.5.2 Decision synchronization

Decision synchronization basically corresponds to joint decision making in the context of planning and operation (Cassivi, 2006). These joint decisions are used to drive logistics processes within an individual chain member firm (Simatupang & Sridharan, 2004). Planning part combines decisions regarding long term planning and measures such as customer service levels, selecting target markets, product range, forecasting and promotion. The operational part deals with integrating order generation and delivery process which can be in the forms of replenishment of the products to the shops and delivery schedule (Simatupang & Sridharan, 2004). Decision synchronization brings chain members together and instills a feeling of belongingness in which all decisions are geared towards a mutual goal of better serving the end customers (Simatupang & Sridharan, 2004). According to Ramdas & Spekman (2000), it decreases the gap between delivery requirements and actual delivery, which in turn, enhances customers' views on fulfillment performance. As a consequence, customers get pleased as they realize that products are well conformed to their requirements at the right time and at the right price. Therefore, decision synchronization leads to a reputation of consistent product availability and on time delivery (Bowersox et al., 2000).

2.5.3 Incentive alignment

Incentive alignment corresponds to the point to which chain members share risks, costs, and benefits. Administration and technology related costs need to be shared equally (Simatupang & Sridharan, 2004). Furthermore, chain members oblige to the collaborative endeavors especially when they conceptualize relevant benefits that can be achieved as a result of collaboration (Kaplan & Narayanan, 2001). According to Corbett et al. (1999), advantages of collaboration include both performance enhancement such as reduced inventory costs and business gains such as increase in sales. Incentive alignment also entails risk sharing between chain members in controlling demand, supply and price. Establishing and implementing incentives such as remunerating receptiveness and sharing the costs of reductions, encourage the chain members to take decisions that are in line with the attainment of profitable supply chain (Simatupang & Sridharan, 2004).

2.6 Driving forces, barriers and enablers of supply chain collaboration

In order to facilitate an effective implementation of collaboration, the organizations must be completely aware of the barriers, driving forces and enablers of supply chain collaboration.

2.6.1 Driving Forces for supply chain collaboration

Collaboration between firms is generally perceived to increase efficiency and reduce costs (Gadman, 2004). According to Lynch (2001) (as cited in Kaveh & Samani, 2009), it is important to realize that collaborative supply chain is driven as a result of a change in corporate vision that considers competition and suppliers as potential collaborative partners in supply chain. Dynamic firms tend to exploit these relationships to achieve efficiencies through shared operations (Gadman, 2004). Most company's perception about collaboration is that it can help them reduce costs, enhance supply chain efficiency and help trading partners become more adaptable in response to customers' demand fluctuations (Kaveh & Samani, 2009). Therefore the two very important reasons why companies enter into collaboration are cost reductions and the need to cater to rapidly changing demands of customers (Fawcett & Magnun, 2011). Third party service providers and retailers lay emphasis on customer needs whilst finished goods assemblers and suppliers focus more on supply chain efficiencies. Firms that focus only on cost reduction are likely to encounter more resistance to change and greater mistrust from managers and employees (Fawcett & Magnun, 2011).

2.6.2 Reasons for entering into collaboration

In addition to these forces, the reasons for firms entering into collaboration with each other may vary from company to company depending mainly on the company's position in the supply chain. Emmett et al. (2006) categorized the reasons why firms decide to enter into collaborative relationships from both buyer and supplier perspectives. The reasons are presented in table 1 and 2 respectively.

Table 1: Top reasons for collaboration - Buyer's perspective (Source: Emmet and Crocker, 2006)

Main reason why companies enter collaborative relationships (buyer's perspective)	***Type of driver***
Price of delivery item	Cost
Secure reliable sources	Cost & Value
Influencing supplier's quality	Value
Improve delivery schedules	Value
Access to supplier's new technology	Value
Reduce internal procurement procedures and costs	Cost & Value
Support JIT initiatives	Cost & Value
Reduce administration procedures and costs (for example, ordering and invoicing)	Cost & Value

Table 2: Top reasons for collaboration - Supplier's perspective (Source: Emmet and Crocker, 2006)

Main reason why companies enter collaborative relationships (supplier's perspective)	***Type of driver***
Secure buyer for product	Cost & Value
Influence customer's quality	Value
Support customer's JIT initiatives	Value
Support forecasts of requirements	Cost & Value
Reduce ongoing administration	Cost & Value
Reduce internal sales procedures and costs	Cost & Value
Price improvement	Cost
Influence/gain access to customer's new technology	Cost & Value

2.6.3 Barriers for supply chain collaboration

According to Fawcett & Magnun (2001), there are two other main categories of collaboration barriers – technology and human related.

2.6.3.1 Technology barriers

With regards to technology barriers, there is a need for a "collaborative technology infrastructure" since the concept of supply chain collaboration is dependent on extensive information sharing amongst the partners (Horvath, 2001). Earlier, electronic data interchange (EDI) solutions were perceived to be harder for small firms to collaborate effectively but recent technology advancements in internet based alternatives to EDI involving lower costs has provided small firms access to the technology and opportunities which allows them to engage easily in more extensive and advanced forms of collaboration (Sandberg, 2005). In spite of this, some technology related barriers may still persist because the issue of successful implementation of the technology still remains a matter of concern. Buying the technology solution at a low price doesn't imply that it will be successfully executed and used (Sandberg, 2005). Hoffman & Mehra (2000) revealed in their study regarding implementation of efficient consumer response (ECR) amongst firms in the grocery industry "If there is one element that can cause the breakdown of any "best designed" supply channel, it is the technology factor. In this stage, a clear understanding of the technology needs of all partners must be assessed followed by information flow planning" (Sandberg, 2005). Another important barrier that should be considered after the successful adoption of technology solution is confidentiality. Horvath (2001) emphasizes that the security concern of the new technology solution is significant in collaborative relationships. Since collaboration involves extensive information sharing amongst partners, it is imperative that information being shared is only accessible to authorized people who are unlikely to transmit this information to competitors. In case of leakage of information to competitors, this could prove to be fatal for company's goal of achieving competitive advantage over its rivals. Secondly, firms should also consider installing proper security measures to make sure that data is transmitted safely and in order to avert information breaches.

2.6.3.2 Human related barriers

Human nature is also one of the major barriers of supply chain collaboration. Most people are averse to change, and the true essence of supply chain collaboration requires a change in mindset and practice (Fawcett & Magnun, 2011). This can lead to confusion and even resistance from company's managers which can dampen the chances of collaboration. It is important for company's management to clearly articulate a clear supply chain collaboration vision so that people can be assured that it won't affect them in anyway and will in fact be beneficial for them in the long term (Fawcett & Magnun, 2011). Trust is another common human related barrier to collaboration. Moore (2003) is of the view that two types of trust are required for collaboration to happen; trust between partners and trust between humans and the technology. Barratt & Oliveira (2001) and Cooke (2003) came up with the following main collaboration barriers (as cited in Janvier & Didier, 2011): inadequate replenishment system in response to demand fluctuations; inefficient forecast planning using visibility of point of sales (POS) customer demand; ineffectiveness to control the forecast review processes; absence of trust and information sharing between partners; non presence of an integrated decision support system to supply customer, consumer and market data; inadequate and inconsistent performance measures and non-aligned and incompatible objectives. Each of these individual barriers poses a challenge to collaboration.

Apart from these, the other most common barriers contributing to failed collaboration as identified by Kaveh & Samani (2009) are listed in table 3.

Table 3: Common barriers to collaboration (Source: Kaveh & Samani, 2009)

Barriers contributing to failed collaboration	***Type of driver***
- Failure to reach an understanding[1] - Lack of shared goals - Different opinion concerning responsibility area - Lack of understanding of owns company's functions - Having realistic expectation	Human Related
Lack of top management support	Human Related
Lack of trust	Human Related
Poor (or lack of) communication	Technology Related & Human Related
Lack of benefit /risk sharing (different opinions of how costs and savings should be shared)[2]	Human Related
Transactional methods of partnering[3]	Human Related
Opportunism and self-interest (may lead to betray)[4]	Human Related
Failure to measure collaborative approach advantages[5]	Human Related
Focus on negative implication[6]	Human Related
Focus and concentrate on short term results[7]	Human Related
Technical difficulties (such as IT problems)	Human Related
Startup factors such as initial costs[8]	Human Related
Time Investment[9]	

[1] Ackerman (1996); Harrison et al. (2008); Mentzer et al. (2000);
[2] Emmett (2006); Harrison et al. (2008)
[3] Czaplewski et al. (2002); Emmett (2006); Mentzer et al. (2000); Harrison et al. (2008); Min et al. (2005)
[4] Mentzer et al. (2000); Harrison et al. (2008)
[5] Czaplewski et al. (2002);
[6] Harrison et al. (2008)
[7] Emmett (2006)
[8] House et al. (2001)
[9] Mentzer et al. (2000)

2.6.4 Key enablers

In order to overcome the barriers contributing to unsuccessful collaboration, possible "enabling strategies" should be worked out which can facilitate effective implementation of supply chain collaboration. According to Mentzer et al. (2000), the key enablers for ensuring successful collaboration includes: trust, openness, leadership, longevity of the relationship and benefit sharing. In addition to these, some other enablers as suggested by Kaveh & Samani (2009) that might be implanted in order to achieve the desired results are shown in table 4.

Table 4: Key enablers of supply chain collaboration (Source: Kaveh & Samani, 2009)

Key Enablers
Two way information sharing and data transparency (communication) Trust and commitment
Top management support[10]
Financial and non-financial investments including: - time - money - training, and - right and up-dates technology
Ability to understand, measure, and allocate the benefits and losses of collaboration[11]
Definition and understanding of[12] - Scope, goals and objectives of operation - Roles - Expectation - Condition of satisfaction
Common interest[13]
Openness[14]
Mutual help[15]
Real, tangible, and substantial rewards (financial and non-financial) for all partners[16]

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[10] Mentzer et al. (2000); Lambert et al. (2001); Levi et al. (2003); Emmett et al. (2006); Min et al. (2005)
[11] Czaplewski et al. (2002); House et al. (2001); Langley (2000); Lynch (2001); Min et al. (2005)
[12] Czaplewski et al. (2002); House et al. (2001); Mentzer et al. (2000); Levi et al. (2003); Lynch (2001); Min et al. (2005)
[13] Mentzer et al. (2000); Emmett et al. (2006); Min et al. (2005)
[14] Mentzer et al. (2000)
[15] Lambert et al. (2001); Mentzer et al. (2000)
[16] Czaplewski et al.(2002); Emmett et al. (2006); House et al. (2001); Mentzer et al. (2000)

Kaveh & Samani (2009) are of the view that enablers such as two way information sharing, suitable level of investment and right mix of channel partners must be in place before commencing of any kind of partnership. Furthermore, the rationale to term them as enablers for collaboration is because of their considerable impact on sustaining collaborative relationships in case they operated properly.

2.6.5 Benefits of logistics collaboration

Some of the benefits of supply chain collaboration include lowered inventory risk and costs along with decrease in warehousing, distribution and transportation costs (Kaveh & Samani, 2009). As far as the long term perspective is concerned, it will significantly enhance customer responsiveness, increase flexibility for changing market conditions, and lastly improve customer service and satisfaction levels (Czaplewski et al., 2002).

Chapter 3:

Solution Approach

3.1 Introduction

The process of supply chain collaboration starts the moment the firm is convinced about entering into collaboration. The process of supply chain collaboration consists of three main parts: pre-qualification of potential partners, partner selection and profit allocation amongst the partners. The supplier database considered for this study included 1233 firms. The database included important suppliers' information such as region, country, industry sector, market capitalization and international securities identification number (ISIN). The supplier database can be found in the CD attached to the thesis. The fact that the database has been developed by Sustainalytics, an award winning global investment research firm specialized in environmental, social and governance (ESG) research and analysis, it can be safely assumed that all false information is excluded from the database. However, the original database had some limitations for our study; for instance, it only covered North America and Europe regions. In this competitive global market, it is important to include suppliers from China, India and Brazil. Therefore, in order to include more multiplicity to our study, a fictitious data is added to cover other regions of the world. Since cluster analysis method is more efficient for numeric data rather than mixed data sets such as numeric and categorical values, only 29 suppliers are considered for this study. This is because assigning numeric data to 1233 firms' different characteristics can be a daunting task. However, an algorithm could have been made to automatically assign numeric data to 1233 firms' different characteristics. This is beyond the scope of this thesis. As a result, the database used for the study is fictional. But the pre-qualification method of potential suppliers employed in the study can easily be extended to 1233 firms or more and can provide a useful guideline as to how methods such as analytical network process (ANP) and cluster analysis can be used in conjunction to reduce a large set of potential suppliers to smaller manageable number by ranking them according to a pre-defined set of criteria.

The steps involved in the process of supply chain collaboration in our solution approach are summarized in figure 4 as shown below:

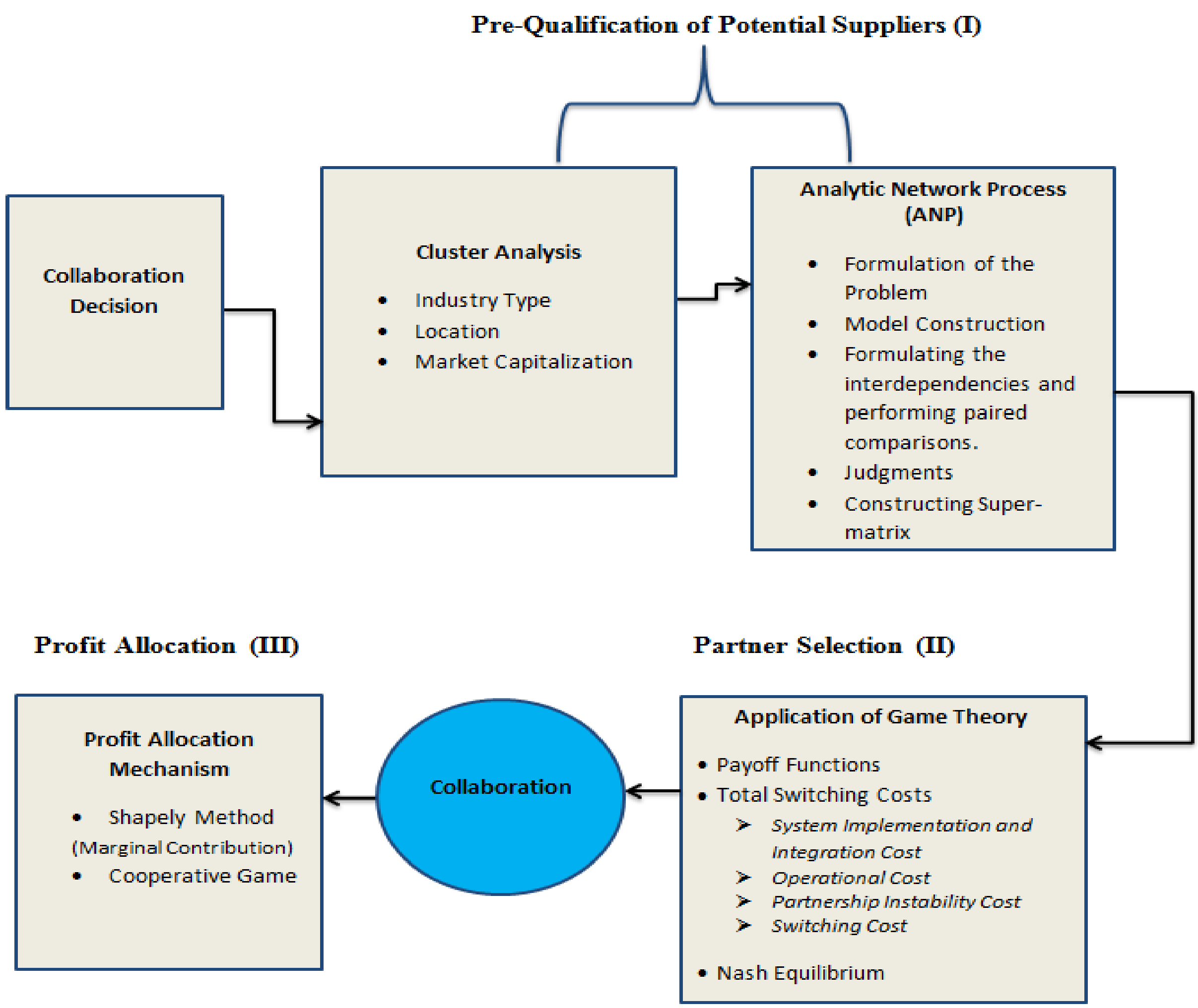

Figure 4: Summarization of the steps involved in the process of supply chain collaboration

3.2 Process of Partner selection for supply chain collaboration

3.2.1 Pre-Qualification of Potential Partners

Holt (1998) defined pre-qualification as "a process of reducing a large set of potential suppliers to smaller manageable number by ranking the suppliers under a pre-defined set of criteria". The major benefits of pre-qulification of suppliers are as follows (Holt, 1998):

1) It reduces the possibility of worthy suppliers being rejected at an early stage.
2) It optimizes the resource commitment of the buyer toward purchasing process.
3) By applying pre-selected criteria, the pre-qualification process is streamlined.

Pre-qualification is a systematic process of ranking several suppliers under conflicting criteria. (Ravindran & Warsing, 2012). It is considered to be a multiple-criteria ranking problem that needs the buyer to do trade off amongst the conflicting criteria, some of which might be qualittative (Holt, 1998). Boer et al. (2001) have mentioned several techniques for pre-qualification. Some of these techniques include, categorical methods, cluster analysis, data environment analysis (DEA) case based reasoning (CBR) systems, and multi-criteria decision making method (MCDM). Several authors as cited in Ravindran & Warsing (2012) have examined several methods of pre-qualification of suppliers. Weber & Ellram (1992) and Weber et al. (2000) have come up with DEA methods for pre-qualification. Hinkel et al. (1969) and Holt (1998) have developed cluster analysis for pre-qualification and lastly, NG & Skitmore (1995) came up with CBR systems for pre-qualification.

In this thesis, the pre-qualification process of potential suppliers is carried out through integration of two methods: cluster analysis and analytical network process (ANP). Initially, cluster analysis is performed that will group partners of interest into clusters. Partners of interest are influenced by factors such as industry type, location and market capitalization. The next step would be to apply the ANP method so that criteria weight and the partners' final rating for selection process can be determined. The reason behind using both these techniques is to further streamline the process of partner selection. In this section, cluster analysis and ANP methodologies will be discussed in detail and will provide a framework as to how these two techniques can be used during the pre-qualification stage of the supply chain collaboration process.

3.2.1.1 Cluster analysis

The first step of partner selection for supply chain collaboration is to carry out cluster analysis. Cluster analysis or clustering is the task of grouping a set of objects in such a way that objects in the same group (called cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters). The main aim of cluster analysis is that objects within a group should be related or similar to one another and distinct from (unrelated) the objects in the other groups (Hinkle, et al., 1969). According to Holt (1998), the greater the likeness (homogeneity) within a group and larger the variance between groups, the finer or more distinct the clustering.

In the context of supply chain management, Porter (1998) defines clusters, as "geographic concentrations of interconnected firms, specialized suppliers, service providers, firms in related industries, and associated associations in particular fields that compete but also cooperate". Cluster analysis helps to split the set of potential suppliers into small clusters in which the clusters grouped together are elements most alike to each other and distinct those from other cluster elements (Holt, 1998). In supply chain management, cluster analysis is normally used during the pre-qualification stage of supplier selection process. Narrowing down the options helps in facilitating an effective analysis and more thorough scrutiny of the remaining suppliers (Timmerman, 1986). This also diminishes the likelihood of refusing good suppliers initially in the supplier selection process. In the context of supply chain management, the main aim of cluster analysis technique is to filter a large set of potential suppliers into more manageable subsets (Holt, 1998).

The technique is particularly useful for large high dimensional supplier databases. For instance, if a prospective retailer wants collaboration with a food and beverage company located in North America region and having a market capitalization of at least $1 million, it will be worthwhile to filter out only those prospective suppliers which fulfil these criteria. In our study, cluster analysis incorporates three factors of interest: industry type, location and market capitalization. It is assumed that the suppliers are all ISO 9000 certified.

In order to perform cluster analysis, NeuroXL Clusterizer software is used. The software is integrated into Microsoft Excel so as to eliminate the need to export data and import the results. NeuroXL Clusterizer uses optimized neural network technology to carry out cluster analysis quickly and efficiently.

An excel sheet containing data of 29 suppliers is used. The data includes important information such as region, market capitalisation and industry type as depicted in table 5 below.

Table 5: Potential Suppliers' Data Sets

No.	Name of Company	Industry Type	Market cap. (Year end, Millions (USD)	Country
1	JBS S.A	1.30	68840.00	5.00
2	A123 Systems, Inc.	1.80	17.00	1.00
3	Aaron's, Inc.	1.60	2290.00	2.00
4	Nestle	1.30	51861.00	5.00
5	Pepsico	1.30	59749.00	5.00
6	Unilever	1.30	3922.00	6.00
7	Accenture Plc.	1.70	45908.00	4.00
8	Accretive Health, Inc.	1.80	1263.00	2.00
9	ACE Limited	1.70	28764.00	3.00
10	Acme Packet, Inc.	1.10	1601.00	4.00
11	Procter & Gamble	1.30	10952.00	5.00
12	Activision Blizzard, Inc.	1.30	12584.00	6.00
13	Adobe Systems Inc.	1.40	19078.00	9.00
14	ADTRAN Inc.	1.40	1275.00	5.00
15	Advance Auto Parts Inc.	1.60	5451.00	5.00
16	Advanced Micro Devices, Inc.	1.80	1943.00	5.00
17	Advantage Oil & Gas Ltd.	1.10	535.00	5.00
18	General Mills	1.30	2732.00	5.00
19	Kraft	1.30	657.00	8.00
20	BRF	1.30	1044.00	6.00
21	Aetna Inc.	1.20	16264.00	9.00
22	Affiliated Managers Group Inc.	1.40	7672.00	1.00
23	Aflac Inc.	1.70	24913.00	2.00
24	Dole Food Company	1.30	5028.00	5.00
25	Bunge Limited	1.30	880.00	5.00
26	Agilent Technologies Inc.	1.20	15413.00	5.00
27	Sysco Corporation	1.30	4846.00	5.00
28	Agnico-Eagle Mines Ltd.	1.20	8463.00	9.00
29	Grupo Bimbo	1.30	16535.00	5.00

As part of cluster analysis, the region and industry type data has been assigned a numeric value.

Table 6: Numeric value for industry type

No.	Industry Type	Numeric Value
1	Automobiles	1.1
2	Aerospace & Defense	1.2
3	Food & Beverage	1.3
4	Machinery/Industrial Goods	1.4
5	Pharmaceutical	1.5
6	Telecommunication	1.6
7	Logistics	1.7
8	Retails	1.8
9	Logistics	1.9

Table 7: Numeric value for region

No.	Region	Numeric Value
1	Africa	1
2	Asia	2
3	Central Asia	3
4	South East Asia	4
5	North America	5
6	South America	6
7	Middle East	7
8	Europe	8
9	Australasia	9

The tables 6 & 7 represent the numeric values assigned to the industry type and country respectively.

As a result of cluster analysis, new groups emerge which includes companies having similar characteristics. In chapter 4, numerical example will be provided as to how cluster analysis can be performed on supplier database.

3.2.1.2 Analytical Network Process (ANP)

Analytical network process (ANP) is a combination of two branches. First branch contains control hierarchy or network of criteria and sub-criteria which control the interactions present in the system under investigation. Second entails a network of influences between the elements and the clusters (Saaty, 2001). The decision problem which is studied with the ANP is normally analyzed via control hierarchy or a network. A decision network consists of clusters, elements and links. A cluster is basically group of related elements. For each control criterion, clusters of the system with their elements are identified. Interactions and feedbacks within the clusters are known as inner dependencies and interactions between clusters are known as outer dependencies. (Saaty, 1999).

According to Bayazit (2007), inner and out dependencies helps decision makers to apprehend and characterize the concepts of influencing and being influenced, amongst clusters and elements with regard to a particular element. Subsequently, pairwise comparisons are attained methodically which includes all the combinations of element/cluster relationships. ANP employs exactly the same comparison scale (1-9) as AHP does. Comparison scale allows the decision makers to combine experience and knowledge intuitively (Harker & Vargas, 1990) and specifies how many occasions an element dominates another with regard to the criterion. This allows decision maker to communicate his preference between each pair of elements as "equally important, moderately important, more important, strongly more important, very strongly more important, and extremely more important" and these descriptive preferences can then be interpreted into numerical values 1, 3, 5, 7, 9 respectively, with 2,4,6 and 8 as intermediate values for comparisons amongst two consecutive judgments (Bayazit, 2007). The comparison scale used by the ANP Saaty (1999) is shown in table 6.

Table 6: Saaty Scale used for Pair-Wise Comparison Matrix

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong or Demonstrated Importance
9	Extreme Importance
2,4,6,8	Intermediate values between adjacent scale values

The synthesized results eventually come up after the pairwise comparisons. Next, the synthesized results of control systems are conjoined so that the best outcome can be determined. As a result of that, set of priorities of the alternatives can be found out. Bayazit (2007) explained the step by step approach of the ANP methodology as follows:

Step 1: Model development

Initially, one network for each control criterion is found out. After that, all the criteria that might affect the decisions are determined. Next, clusters for each network are found out and one cluster will be the alternatives. Finally, the relevant criteria are combined together into the same clusters.

Step 2 – Formulating the interdependencies and performing paired comparisons between the clusters/elements

Next, for each control criterion, a cluster versus a cluster matrix is created with one or zero as an input depending on whether the left hand side cluster influences or doesn't influence a cluster located at the top of this matrix. Similar process is repeated for criteria versus criteria matrix. Again with one or zero as an input and depending on whether a left hand side criteria influences or doesn't influence criterion situated at the top of this matrix. Paired comparisons of clusters, elements and alternatives are performed to obtain eigenvectors and to form super matrix (Bayazit, 2007). The paired comparisons are done as follows:

(A) Cluster comparisons. Firstly, paired comparison is performed on the clusters that influence a given cluster with regards to control criterion. As a result, the weights are obtained during the process and then they are used to weight the elements in the corresponding blocks of the super matrix relating to the control criterion.

(B) Comparisons of elements: In this, paired comparisons on the elements inside the clusters are performed. Then the elements in the cluster are compared depending on their influence on an element in another cluster to which they are related (or on the elements in their own cluster).

(C) Comparisons for alternatives. In this, comparison of the alternatives with respect to all the elements is carried out.

Step 3 – Constructing the super matrix

Next, an un-weighted super matrix is obtained. It indicates the pairwise comparisons of the criteria. In the un-weighted super matrix, the columns might not be column stochastic. Therefore, the blocks of the un-weighted matrix are multiplied by the priority of corresponding influencing cluster in order to attain the stochastic matrix. The stochastic matrix comprises of columns that all add up to one. Next, the super matrix is raised to large powers in order to capture first, second and third degree influences. The powers of the super matrix are raised till the differences between consecutive matrix elements reach a really small number. Next, each block is normalized so that final priorities of all the elements in the limit matrix are obtained. The final step involves choosing the highest priority alternative (Bayazit, 2007).

3.2.1.2.1 Application of analytical network process (ANP)

Analytical network process approach was developed by Thomas L. Saaty in 1996 and is considered as a generalization of analytic hierarchy process (AHP). According to Saaty (2005), ANP uses grid instead of hierarchy used in AHP and enables relations of dependence between the clusters and its elements.

The decision problem in our case is selecting the top ten suppliers after cluster analysis has been performed. In the past, partners used to be selected on the basis of few factors such as ability to meet quality requirements, price offering and compliance with delivery schedules. But nowadays, many other factors seem to be taken into consideration (Muralidharan et al., 2002). In the literature review of Cheraghi et al. (2004), 86 papers linked to partner selection factors in the timeframe 1990-2001 are summarized. They drew the top 30 most important factors for supplier ranking with quality ranking first, delivery second and price third. Similarly, Zhang et al. (2003) concluded somewhat similar top three- price first, quality second and delivery third. In the nutshell, many factors are important for partner selection but price, quality and delivery were concluded to be the top three most important partner selection factors in most of the studies.

For our study, the factors presumed to be important for collaboration from both the perspectives of the suppliers and retailers include performance, compatibility, information technology systems, capability, service, risk management and long term relationship. The factors and the criterion for each factor are presented in table 7. Retailers usually look for capable, compatible and long term oriented suppliers who can provide high quality products at economical prices and can commit to long term relationship. On the other hand, suppliers generally look for retailers who are honest, trustworthy and possess state of the art supply chain management information systems so that information related to point of sales can be shared freely in a transparent manner.

Table 7: Partner Selection Factors and their Criterions

Factors	Criterion
Performance	Quality Performance (e.g. ISO 9000 accreditation)
	Delivery
	Lead Times
	Development Speed
Compatibility	Cost of Service
	EDI Capability
	Location (Geographic Spread)
	Strategic Objectives
	Management Attitude
	Information Sharing & Mutual Trust
IT	Supply Chain Systems
	Current Technology (Product & Process)
	Communication Systems
Capability	Production Facilities and Capacity
	Surge Capacity
	Reciprocal Arrangements
	Financial Position
	Forecasting Capabilities
Service	Flexibility (payment, freight, price reduction, order frequency and amount
	Ability to modify the product service
	Technical Support
	After Sales Service (Warranties and claims policies
Risk Management	Willingness to share risk
	Clause for Arbitration and escape
Long Term Relationship	Long Term Orientation
	Collaboration Possibility

During the process of partner selection, firms should not only consider the financial contribution to the alliance, but also take into account other criteria such as top management attitude, organizational culture, technical capabilities and long term orientation. Most of the above mentioned criteria are qualitative and cannot be simply assessed by using mathematic formulation (Chen et al., 2008). In addition to evaluating how the prospective partner will contribute to pre-determined criteria, the firm should check their motivations and priorities for going into collaboration. The top level management of a particular firm may have various motivations in mind for collaborating but with different priorities in mind, which in turn, influences the weighting on criteria for assessing the suitability of prospective partners. On the other hand, the method of deciding weights on the criteria also discloses the priority of the motivations. This denotes that the relative weights set for each criteria and the priority of motivations interact with each other. Therefore when criteria weights are set, the firm should evaluate whether its initial priority of motivations is still maintained. If it is still kept, the relative weights of these criteria are then used to assess the prospective partners in the selection procedure. However in case , it is not kept, the firm should reassess the weighting process or evaluate again the weights for the criteria before carrying out the partner evaluation and selection process so as to avoid choosing unsuitable partner (Chen et al., 2008). Since interdependence in relationships exists in the collaboration criteria, the analytical process network (ANP) method is suitable for partner selection for collaboration (Saaty, 2005). In the following sections, we will demonstrate the various steps of ANP conducted in super decisions software and the criteria used in the decision making process.

Step 1: Model development

The first step involves identifying clusters, elements and links. After that the network of the problem is built on super decisions software as shown in figure 5

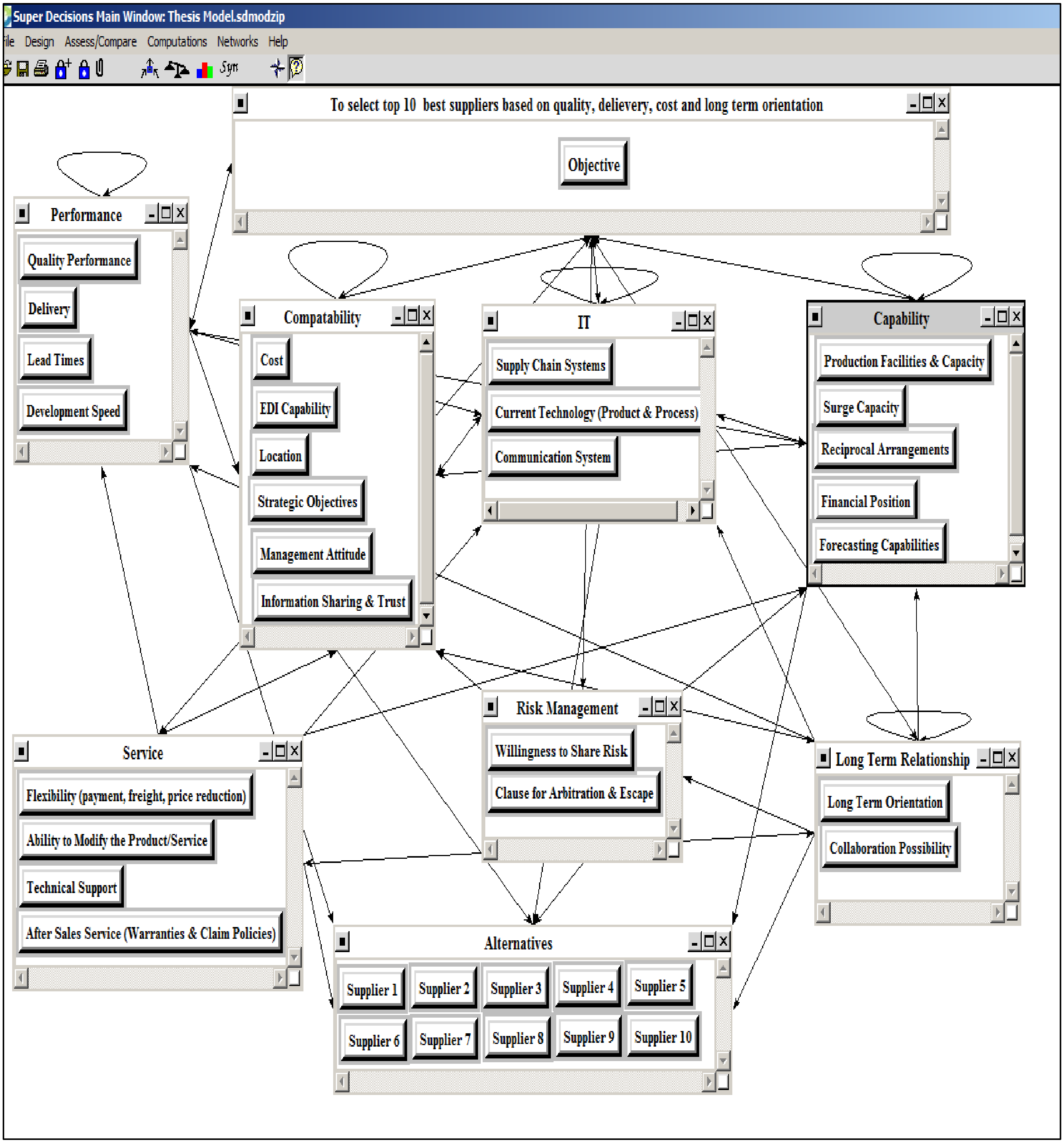

Figure 5: Network Model of the Problem

Figure 5 presents the network model of the problem. It includes clusters, elements and links. As can be seen in the figure, the model comprises of 8 clusters (performance, service, compatibility, risk management, Information technology (IT), alternatives, long term and capability), each one composed by its respective elements shown in figure 5. Ten partners, namely suppliers 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 were considered as alternatives for the selection. The relations between the clusters, elements and alternatives are given in figure 5.

It can be seen in the network model, ANP method allows dependence relations amongst elements and clusters. Such relations are denoted by arrows, when the dependence occurs between clusters over another cluster. Similarly when there is dependence between elements of the same cluster, it is represented by a loop. In case of an arrow from a cluster to another, it's enough that at least one element of the original cluster is associated to an element of the destination cluster (Saaty, 2005).

Step 2: Determining the interactions between and within clusters and elements

The next step is to determine interactions between and within clusters and elements. For our model, we defined 8 clusters. The clusters and elements within the clusters along with their interdependencies are defined as follows:

1. Performance

This criterion defines the anticipated performance from the prospective partners. It has 4 sub-criteria as shown below:

1.1. Quality performance

It is assumed to be dependent on cost, current technology, financial position and production facilities & capacity. Obviously, if the firm has a better financial position, it can afford to enhance its quality performance by upgrading existing technology or buying state of the art production equipment.

1.2. Delivery

The partner's ability to deliver products to its customers on time depends on how effectively and efficiently firm develops those products. Lead times, location and supply chain systems are also important aspects which can affect the delivery. Therefore, delivery is assumed to be dependent on development speed, lead times, and location and supply chain systems.

1.3. Lead times

Lead time refers to the time it takes for the partner to develop and deliver the goods to the customer. It's dependent on communication system, development speed, EDI capability, forecasting capabilities, information sharing & trust, location and production facilities & capacity since all these factors play an important part in either increasing or decreasing the lead times.

1.4. Development speed

Development speed depends on the current technological processes in place, information sharing between the customer and the supplier, lead times (how long the partner's supplier takes to provide the required components), production facilities and supply chain systems.

2. Compatibility

Compatibility criterion basically gives an indication whether the prospective supplier is compatible in terms of cost, location, strategic objectives, management attitude, information sharing & trust and EDI capability.

2.1. Cost

It is dependent on financial position and location. Obviously, if a partner is located in China, it can hire cheap labour and, in turn, offer reduced prices to its collaborating partner. If the financial position of the partner is good, then it is likely that partner would offer reasonable price to its collaborating partner in the hope that it will result in long term relationship.

2.2. EDI capability

The EDI capability criteria are assumed to be dependent on cost, communication systems, financial position, and management attitude and supply chain systems since it involves lot of communication between the collaborating partners and thus it required for the prospective partners to either acquire this capability or may be upgrade its EDI capability in case if it is non-compatible. This requires dedicated efforts from the management and also substantial costs may be involved.

2.3. Location

Location is dependent on strategic objectives since some firms objective may be to access new markets through collaboration or some firms just want to exploit the gains of cheap labour in a country where labour price is relatively low.

2.4. Strategic objectives

They are dependent on collaboration possibility, cost, financial position, information sharing & trust, location, long term orientation, management attitude and willingness to share risk. These aspects play an important role in determining the firm's strategic objectives.

2.5. Management attitude

This is dependent on cost, forecasting capability, flexibility, collaboration possibility, financial position, information sharing & trust, location, long term orientation, strategic objectives and willingness to share risk. This is because if there exists a chance of collaboration, it is likely that the management attitude will be influence by that possibility.

2.6. Information sharing & trust

This is dependent on communication systems, collaboration possibility, flexibility, forecasting capabilities, long term orientation, strategic objectives and management attitude. Obviously, if the firm is convinced that its prospective partner's communication systems are safe to transmit information without worrying that the sensitive information will reach its competitors and if the prospective partner is willing to enter into collaboration for a long time, it is likely, that the firm will be comfortable with the idea of sharing information.

3. Information Technology (IT)

This criterion refers to the IT capability of the prospective firms. It has 3 sub-criteria as shown below:

3.1. Supply chain systems

These are dependent on cost and financial position. A wealthy firm can afford to install modern supply chain systems or upgrade it to be compatible with its prospective partner's one.

3.2. Current technology (product & process)

This is dependent on cost and financial position. A firm in good financial state can afford to upgrade its existing technology or buy new one.

3.3. Communication systems

These are dependent on current technology and location. This is because if the prospective partner is based at a considerable distance from the firm, it might have to upgrade its existing technology or look for a partner whose is located nearby.

4. Capability

The capability criterion gives an indication about how capable the prospective partners are.

4.1. Production facilities & capacity

These are dependent on cost, financial position and location. Production facilities will be modern if the financial position of the firm is good and in turn it can offer goods at a reduced cost since economies of scale can be realized as a result of modern production facilities and capacity.

4.2. Surge capacity

This is dependent on cost, development speed, financial position, reciprocal arrangements and strategic objectives. Only a firm which has a good financial state can think about adding additional equipment so in order to meet the demand at peak times. In this case, the partner might ask for a higher price so as to overcome the additional expenses incurred on adding additional machineries.

4.3. Reciprocal arrangements

These are dependent on cost, financial position, and strategic objectives. It incurs additional costs to have reciprocal arrangements.

4.4 Financial position

This is dependent on cost of service. A firm in a good financial state can offer price discounts to its customer hence the cost of service will be low in that case.

4.5 Forecasting capabilities

These are dependent on communication systems, current technology, EDI capability, supply chain systems, information sharing & trust and location. Accurate forecasting can only happen if there exists a proper channel which can facilitate information sharing and trust between the collaborating partners.

5. Service

The service criterion gives an indication regarding how helpful or flexible the prospective partners can be in terms of flexibility, ability to modify product or service, technical support and after sales service.

5.1 Flexibility (Payment, freight and Price Reduction)

This is dependent on collaboration possibility, financial position, long term orientation, management attitude and strategic objectives. Possibility of a long term relationship acts as an incentive for firms to offer flexibility in terms of payments.

5.2 Ability to modify product & service

This is dependent on current technology, information sharing & trust, lead times, production facilities & capacity and supply chain systems. Information sharing can help prospective partners to better understand the each other requirements thus making it easier to modify product or service quickly.

5.3 Technical Support

This is at the discretion of the management to decide how much technical support to offer to customers after a product or service has been bought from them.

5.4 After Sales Service (Warranties & Claim Service)

This depends on management attitude, collaboration possibility and strategic objectives. If the firm is interested in engaging in long term collaboration with the prospective partner then it will likely consider providing good after-sales service.

6. Risk Management

This criterion refers to the risk management policy of the prospective suppliers.

6.1 Willingness to Share Risk

This depends on cost of service, financial position, information sharing & trust, management attitude and strategic objectives. If the financial state of the firm is not good enough, then it might not be willing to share the risk equally. Similarly, if it is charging high amount of money from its customer then it can think about sharing risk with its customer

6.2 Clause for Arbitration & Escape

This is dependent on management attitude and strategic objectives. Because strategic objectives can require a firm to have strict clauses for arbitration and escape so it can be difficult for the partner to leave collaboration. It also depends on the attitude of the management.

7. Long Term Relationship

This aspect relates to the possibility of a long term relationship between the prospective partners.

7.1 Long Term Orientation

This is dependent on all the sub criterions as mentioned above. All sub-criterions are equally important when considering long term relationship.

7.2 Collaboration Possibility

Collaboration possibility also depends on all the sub-criterions mentioned above.

The interactions between and within clusters and their elements are summarized in figures 6, 7 and 8.

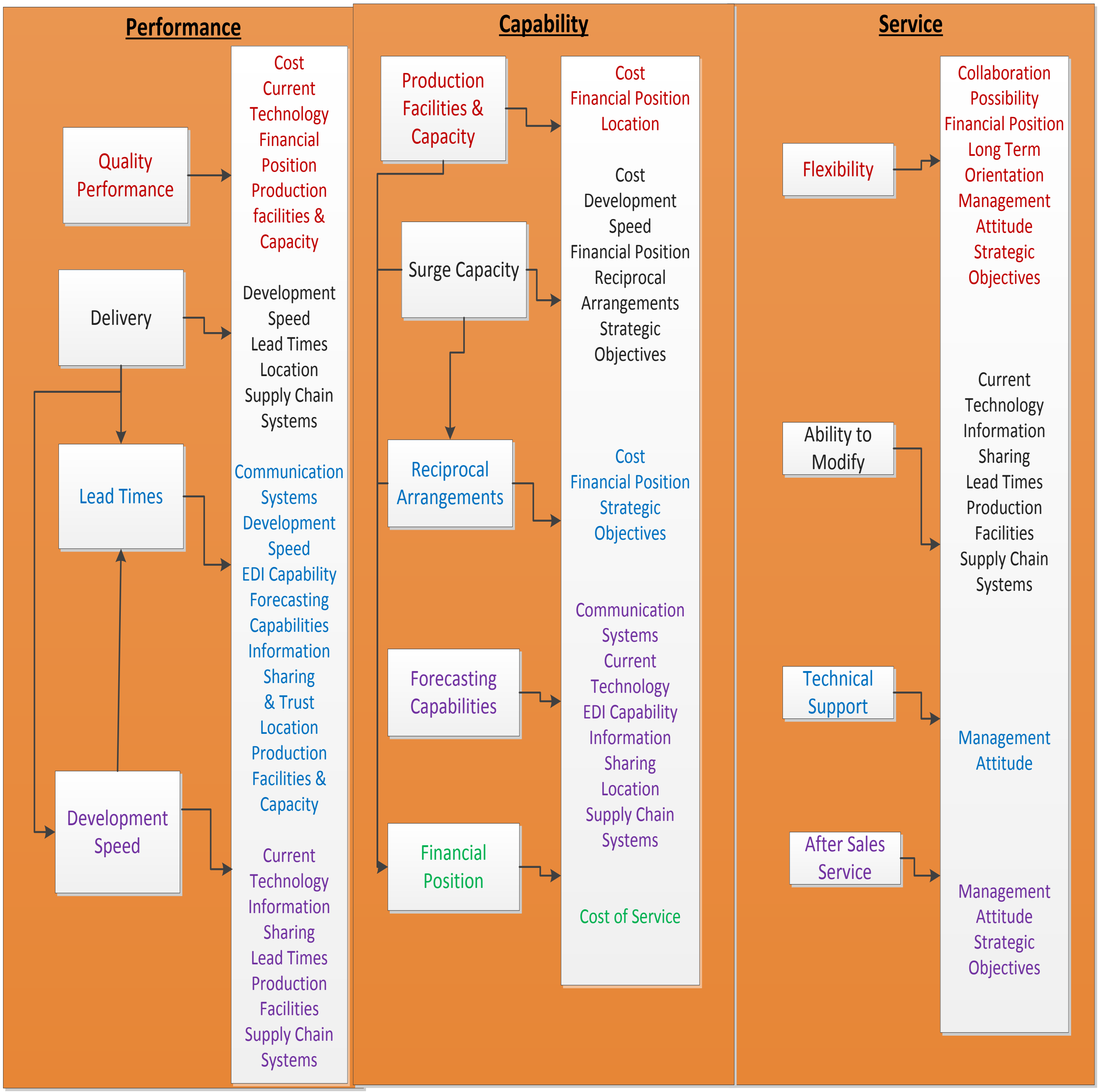

Figure 6: Interactions between and within clusters and elements for "Performance, Capability and Service".

Figure 7: Interactions between and within clusters and elements for "Compatibility, IT and Risk Management".

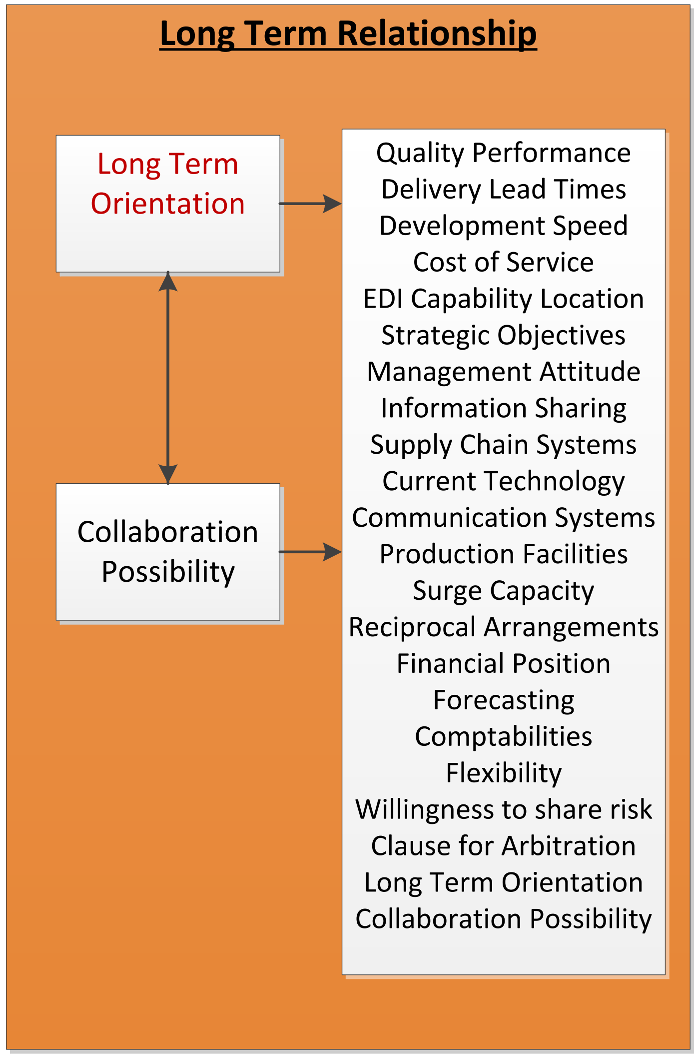

Figure 8: Interactions between and within clusters and elements for "Long Term Orientation and Collaboration Possibility

Step 3: Pairwise comparisons

In step 3, the decision makers set their preferences through the development of the comparison matrices of the clusters, elements and rating, based on Saaty's fundamental scale. The comparisons to be made are those in which an element of a cluster has a relation of dependence with at least two elements of another cluster. Moreover, pairwise comparison of each element with respect to the adopted ratings is made.

Step 4: Development of super matrices

After pairwise comparisons, the un-weighted and weighted super matrixes along with limit matrix are developed. The un-weighted super matrix comprises of priority vectors placed in columns, gained through pairwise comparisons. Details about super matrices will be discussed in detail in chapter 4 i.e. numerical application. Finally, the rankings of the alternative partners are obtained and top 10 suppliers are shortlisted.

3.3 Partner selection

Partner selection is procedure of identifying ideal partners that can provide right quality products and/or services at the right place, at right quantities and at the right time (Sonmez, 2006). Proper identification of potential partners is of utmost importance for achieving successful supply chain management (Lasch & Janker, 2005). Proper identification of partner selection decreases the purchasing costs and also enhances corporate competitiveness (Ghodsypour & Brien, 2001).

In the partner selection process for collaboration, identification of suitable decision making criteria for choosing the right partner is of utmost importance. The decision making criteria to be used for partner selection will vary across a variety of industries. For example, in pharmaceutical industry, the most important criteria would be health and safety considerations, followed by quality and delivery. Similarly, in automobile industry, reliability, durability and quality would be the three most important selection factors. In the context of supply chain collaboration, the prospective partners' decision whether to engage in collaboration with each other or not is to a large extent influenced by the partner selection criteria.

According to Kuo & Lin (2011), selection of suitable partners is one of the essential strategies of improving the product quality of any organization since it directly influences companies' reputations. The task of partner selection is more complicated especially in case different partners are already collaborating and want to select a partner for improving the sustainability of their supply chain collaborative network (Saiz & Rodríguez, 2010).

Bhutta & Huq (2002) are of the view that partner selection process needs consideration of multiple objectives and thus can be regarded as a multi-criteria decision making problem (MCDM). MCDM approaches comprise of a set of concepts, methods and techniques that aim to facilitate individuals or groups to make decisions involving multiple criteria and multiple agents (Saiz & Rodríguez, 2010). In this regard, several multi criteria approaches have been suggested for solving partner selection problems; these include multi-objective programming (MOP), analytic hierarchy process (AHP) and analytic network process (ANP) and vendor profile analysis (VPA) (Cheng, 2007). ANP method, developed by Saaty, allows in resolving problems that entail both qualitative and quantitative criteria as well as take into consideration the interdependence and feedback among these criteria.

In this thesis, we will use game theory for collaboration partner selection. The various details of game theory are presented as follows:

3.3.1 Game theory introduction

According to Myerson (1991) game theory is defined as "the study of mathematical models of conflict and cooperation between intelligent rational decision makers. Game theory provides general mathematical techniques for analyzing situations in which two or more individuals make decisions that will influence one another's welfare".

It offers tools, methods and models to examine coordination, collaboration, and competition in the context of supply chain management (Meca & Timmer, 2007). Game theory is considered to be an important tool with regards to supply chain management problems involving multiple agents (retailer, manufacturer, buyer, government etc.), with conflicting objectives (Cachon & Serguei, 2004). It helps in facilitating decision makers to improve the cooperative effectiveness of the partners involved (Zhu & Dou, 2010).

Different entities in the supply chain are known as players. A "game" in the context of supply chain management has four main components (Froeb & McCann, 2008):

1. The players (potential supply chain partners e.g. supplier, retailer, manufacturer, distributor etc.)
2. The rules that confine the game (e.g., laws, customer deadlines etc.)
3. A set of decisions or selections that the players might execute (involve or not involve)
4. The payoffs as a result of making those selections.

3.3.1.1. Classification of the game

Traditionally, game theory can be divided into two branches: non-cooperative and cooperative game theory. In the supply chain management literature, most academic articles and journal papers have, over the past few years, focused only on the application of non-cooperative game theory. On the other hand, papers applying cooperative game theory to study supply chain management didn't receive much attention. According to Cachon & Netessine (2003), the application of cooperative game theory, in the context of supply chain, is scarce as compared with non-cooperative game theory, owing to the rising trend of bargaining and negotiations in supply chain relationships. In addition, a non-cooperative game clearly specifies the options, incentives and information of the "players" and tries to predict how the players will play the game whereas cooperative game theory only concentrates on the outcome of the game in terms of value generated as a result of cooperation of a subset of players (Cachon & Netessine, 2003). The characteristics of non-cooperative and cooperative game theory are described as follows.

Non-Cooperative

In non-cooperative games, the players select their strategies simultaneously and stay firm on their selected strategies (Cachon & Netessine, 2003). It is not possible for players to collaborate or communicate in any way and therefore, it is impossible for them to make binding commitments before selecting their strategies (Nash, 1953). Non-cooperative game theory investigates regarding what action one might expect from the players (Nagarajan and Sosic, 2008), the emphasis being on the specific actions of the players (Cachon, 2004). In this type of game, numerous equilibrium solutions have been recommended such as dominant strategy, Nash equilibrium, and sub game perfect equilibrium (Damme, 1991).

Nash equilibrium: Strategies selected by all players are supposed to be in Nash equilibrium state provided that no player can benefit by changing only their own strategy unilaterally (Osborne & Rubinstein, 1994). According to Nash (1950), every finite game contains at least one Nash equilibrium solution.

Dominant strategy: It is the strategy which accomplishes the highest payoff and is considered to be the best irrespective of the strategies selected by other players.

Sub-game perfect equilibrium: Strategies in an extensive form are said to be in sub-game perfect equilibrium provided that the strategies constitute Nash equilibrium at all decision points.

Cooperative

In a cooperative game, it is possible for players to enter into binding commitments and therefore, players can make side-payments and form coalitions (Cachon & Netessine, 2003). Cooperative game basically studies the set of likely outcomes and examines what the players can attain, what kind of coalitions will form and how will the coalitions that are formed, will divide the outcome and whether the outcomes are robust and steady (Nagarajan & Sosic, 2006). It directly looks at the set of possible outcomes, studies what the players can achieve, what coalitions will form, how the coalitions formed will divide the outcome, and whether the outcomes are stable and robust (Nagarajan & Sosic, 2006). Cooperative game theory does not examine the behavior of the individual players and assumes that once the coalition is formed, the coordination between them is attained one way or the other (i.e. attained either by having binding agreements and assurances or through an appropriate coordination procedure) (Meca & Judith 2007).

In cooperative game theory, a solution concept is one which fulfills a set of assumptions. The important ones are as follows:

Pareto optimality: Total utility is one in which total utility assigned to each player is equal to the total utility of the game.

Individual rationality: Individual rationality is one in which each player should be allocated higher utility than the utility each player attains by acting sans the coalition.

Kick-back: This requires that players be assigned a utility which is always non-negative.

Monotonicity: Monotonicity requires that the allocation to a player should be higher in case the overall utility increases.

Zero sum

Basically, in zero sum games, the profits of all the players are equal to the losses of the players. This means that total winnings sans the total losses for any set of strategies chosen in the whole game must be zero (Neuman & Morgenstern, 1944). Tennis, chess and boxing are example of zero sum games because in these games, one player's win is the other's loss.

Non zero-sum games

In non-zero sum games, the combined gains and losses of the players in the game can be either larger than or smaller than zero (Ken & Binmore, 2007). In other words, there is a possibility for all players involved to either gain or lose together. Examples where non-zero games are used includes stock markets, international trades, information exchange etc.

Player

The participants of the game are known as players. In the context of supply chain management, the players can either refer to manufacturer, supplier, retailer, shipper or a distributor. It is possible to think multiple entities, such as the ones specified above as one player provided that those entities are working in coordination with each other. An example of this scenario will be when a group of retailers, let's say five, is thinking about entering into collaboration with a single big supplier. In this case, group of retailers will be considered as a single player.

Strategy

A player's strategy, in the context of game theory, corresponds to one of the selections he can make in a situation in which the outcome is dependent not only on his own actions but on the action of others (Polak , 2007). In other words, strategy refers to action or series of actions that defines all the possible choices a player can make in every situation. There can be two types of games: simultaneous and sequential. In simultaneous games, the players make decisions without knowing the decisions of their opponents. In sequential games such as chess, each player gets to know the previous decisions of the other player's.

Payoff

Payoff is basically an outcome a player gets after an action or series of actions has been executed by the participating players. The payoff can either be positive or negative.

3.3.2 Application of Game theory for partner selection

Supply chain comprises of a number of decentralized companies who have the prospect of working jointly (Meirvenne & Raa, 2011). Decisions taken by an individual firm in the supply chain will influence the profit of other firms in the supply chain and hence the profit of the supply chain as a whole (Nash, 1953). According to Cachon (2004), game theory is a good way to demonstrate decision making in a situation involving various interdependent entities where the outcome is dependent on the selection made by every entity. In the context of partner selection, game theory tries to model and analyze strategic situations, including various forms of game appropriate for different settings (Nagarajan & Sosic, 2008). In case of partner selection, it will exhibit the likely response of the partners' under different conditions. Game theory assumes that each player attempts to maximize their own value while assuming that other players are also doing exactly the same and that the decisions made by other players' affect each other's values (Nagarajan & Sosic, 2008).

After application of ANP method, there is one question that remains unanswered; what type of collaboration will be best for each partner and what will be the likely reaction of potential partners' for each type of collaboration. After shortlisting the number of partners through cluster analysis and analytical process network approach, it cannot be assumed that prospective partners will readily agree to enter into collaboration. This is because it might not be in the best interest of a particular partner to enter into collaboration whereas it might be beneficial for the other one. In order to determine the win-win solution from the perspective of each partner, a non-cooperative game is designed in where partners make decisions independently in a manner which maximizes their own payoffs. The solution of non-cooperative game is Nash equilibrium.

During the initial stages of partner selection for collaboration, the main focus is on predicting the outcome of the game instead of focusing on specific actions taken by the players. As a result, this problem is structured as a non-cooperative game. In a non-cooperative game, cooperation between partners must be self-enforcing as oppose to cooperative game where players enforce contracts through third parties. A non-cooperative game clearly specifies the options, incentives and information of the "players" and tries to predict how the players will play the game. In our study, we assumed that each partner has three choices of collaboration to make: full collaboration, partial collaboration or no collaboration.

Incentives for each partner can vary depending on the needs of a particular partner. For instance, retailer might be interested in reducing its inventory related costs. For that reason, it would prefer to enter into partial collaboration with the supplier. In partial collaboration, the retailer can get a complete refund from the supplier in case the goods are not sold to the end customer. On the other hand, the incentive for supplier going into partial collaboration with the retailer would be reduction in operating costs as a result of better forecasts, reduced demand variability and better information for sales & operations planning (S&OP). In this case, it seems both the retailer and the supplier seem to be benefiting from entering into partial collaboration with each other. However, in case, supplier and retailer decide to enter into partial collaboration with each other, they need to examine the total switching costs and the net benefits to be realized as a result of choosing partial collaboration. In addition, the total switching costs, and the net benefits for other types of collaboration also need to be examined. Only then partners will be in a good position to make a decision as to which form of collaboration will best suit them.

During the modelling of the game, it is assumed that collaboration, whether partial or full, will ultimately result in cost savings more than that of "no collaboration". Therefore, the decisive factor which plays an important part during the decision making process of the partners is total switching costs. During analysis, for example, if the net benefits are high and total switching costs are low for partial collaboration for both the retailer and the supplier with respect to other types of collaboration; the dominant strategy for the partners would be to enter into partial collaboration with each other. In this case, the partners are said to be in Nash equilibrium because each one is making the best decision while taking into consideration the decisions of others.

Basic assumption

In order to investigate the collaboration mechanism, three modes of collaboration i.e. full collaboration, partial collaboration and no collaboration are proposed in the study. These modes of collaboration are basically developed through a combination of wide range of supply chain contracts such as buy back contracts, quantity flexibility contracts, revenue sharing contracts, quantity discount contracts, and sales rebate contracts. The modes are developed under the assumption that collaboration, be it partial or full, will ultimately result in maximizing the total revenue of the supplier as well as that of the retailer and neither supplier nor retailer has anything to gain by changing only their own strategy unilaterally. However, the characteristics under each mode are subject to change in case supplier or retailer doesn't agree. In this case, it is assumed that the modes of collaboration are developed by the retailer. The characteristics of each mode of collaboration are defined as follows:

Full collaboration

In full collaboration, the partner and the retailer work like a single entity. The characteristics when both the retailer and the supplier work in full collaboration are as follows:

- The administration costs are shared equally between the supplier and the retailer.
- Inventory costs are shared equally**.** Retailer's warehouses and supplier's warehouses may be combined into a single warehouse or alternatively the operational costs of running the warehouses are shared equally by both the retailer and supplier.
- Transportation costs are equally shared between the supplier and retailer.
- Production costs are equally shared.
- Centralized information sharing.

- The profit from the sales of the goods is equally shared between the retailer and the supplier.
- Costs such as system implementation, operational, partnership instability and switching are shared equally between the partners.
- Joint decisions on strategic issues such as production capacities, product design, portfolio joint marketing and pricing plans.
- Information sharing on topics such as bill of materials (BOM), orders, product descriptions, prices & promotions, product & material availability and service levels.

Partial collaboration

In partial collaboration, limited resources are shared between the supplier and the retailer. The characteristics of partial collaboration relationship between the supplier and the retailer are as follows:

- The inventory is completely managed and owned by the supplier until the retailer sells it. This means the administration costs increase at the supplier's end.
- The supplier decides on the appropriate inventory levels of each of the products and appropriate inventory policies.
- Since inventory is completely managed by the supplier, the inventory costs are endured by the supplier alone.
- Transportation costs are fully endured by the supplier.
- Costs such as system implementation, operational, partnership instability and switching are borne separately by each partner.

- Information sharing on topics such as bill of materials (BOM), orders, product descriptions, prices & promotions, product & material availability and service levels.

No collaboration

In no collaboration, supplier and retailer work like separate entities. There is no information sharing on topics such as bill of materials (BOM), orders, product descriptions, prices & promotions, product & material availability and service levels. Other features of no collaboration are as follows:

- The retailer decides on how much to order.
- The inventory costs are endured separately by the retailer and the supplier (Assuming both operate a warehouse and keep inventory stock).
- The administration costs are endured separately by both the supplier and the retailer.
- Production costs are endured by the supplier.
- Transportation costs endured separately by both the supplier and the retailer assuming both have a warehouse.

The costs characteristics of three different types of collaborations are summarized in table 8.

Table 8: Costs Characteristics of three different types of collaborations

Costs	No Collaboration		Partial Collaboration		Full Collaboration	
	Retailer	*Supplier*	*Retailer*	*Supplier*	*Retailer*	*Supplier*
Inventory Carrying Cost	Paid by Retailer	Paid by Supplier	None	Paid by Supplier	Shared	Shared
Transportation Costs	None	Paid by Supplier	None	Paid by Supplier	Shared	Shared
Production Fixed cost	None	Paid by Supplier	None	Paid by Supplier	Shared	Shared
Admisnistration Cost	Paid by Retailer	Paid by Supplier	Paid by Retailer	Paid by Supplier	Shared	Shared
Fixed Ordering Cost	Paid by Retailer	None	None	None	Shared	Shared
Expected Inventory Holding cost	Paid by Retailer	Paid by Supplier	None	Paid by Supplier	Shared	Shared
System Implementation and Integration Cost	N/A	N/A	Paid by Retailer	Paid by Supplier	Shared	Shared
Operational Cost	N/A	N/A	Paid by Retailer	Paid by Supplier	Shared	Shared
Partnership Instability Cost	Paid by Retailer	Paid by Supplier	Piad by Retailer	Paid by Supplier	Shared	Shared
Switching Cost	Paid by Retailer	Paid by Supplier	Paid by Retailer	Paid by Supplier	Shared	Shared

During development of these collaboration modes, phenomenon of counterfeit and refurbished products has been taken into consideration. Counterfeit and refurbished products have become a growing problem in supply chains and have attained significant ground in most of the industries including pharmaceutical, electronics, automotive, consumer products, food and beverage and aerospace. Counterfeiting can impact the stakeholders in a typical supply chain in a number of ways. For example, it can result in lower profits, lost sales and decline in brand equity. As a result of counterfeit and refurbished products, end customers receive substandard, unregulated and unsafe products which can pose a risk to their health and safety. As a consequence, this will likely result in customer dissatisfaction, which in turn, would lead to decline in sales and lower profits. Therefore, it is important for a prospective firm, who is considering collaboration, to ensure that it forms partnership only with authentic and reliable partner(s) who can guarantee provision of high quality original products. In order to account for the possibility of counterfeit and refurbished products being sold to the prospective firm(s), they must have appropriate reactive and proactive measures in place to deal with any kind of eventuality. The framework suggested in our study incorporates two factors namely quality performance and risk management. Quality performance factor ensures that firm is being proactive by having adequate quality control standards to prevent any fake or refurbished products being sold to them. On the other hand, risk management factor includes a strict penalty clause and comprehensive insurance policy to account for any potential loss of sales or brand equity in case of buying counterfeit or refurbished product from their collaborating partner.

Formulation of game

- *Players:* Players refer to potential partners contemplating about entering into collaboration.
- *Strategy:* Strategy refers to complete plan of action a player will select given the set of circumstances that might arise within the game. In this case, the partners' have three strategies to choose from i.e. full collaboration, partial collaboration or no collaboration.
- *Payoff:* It refers to the payout a player gets from arriving at a particular outcome. The payout can be in any measurable form, from currency to utility.
- *Equilibrium:* A point in the game where both players have reached their decisions and an outcome is achieved.
- *Static and Dynamic Settings:* The total additional switching costs are borne only once by the retailer (s) and/or supplier(s) as a result of entering into either partial collaboration or full collaboration mode with each other. Inventory carrying cost, transportation cost,

production fixed cost, administration cost, fixed ordering cost and inventory holding cost are conisdered to be variable costs and are expected to change over period of time.

Assumptions and major variables

a) The ultimate aim of the players is to maximize their profits.
b) There are three types of strategies that players can choose from: full collaboration, partial collaboration and non-collaboration.
c) In each mode, the price, unit cost and the incremental cost of the product are different.
d) The supply and demand of the products will be different under different categories.
e) Each of the two enterprises has an accurate understanding of characteristics and utility but not the action of the other enterprise before making decisions.

3.3.2.1 Game theoretical analysis

The solution concept of a non-cooperative game is Nash equilibrium. In the context of supply chain collaboration, for example, Supplier (A) and Retailer (B) are said to be in Nash Equilibrium if Supplier (A) is making the best decision it can, taking into consideration Retailer's (B) decision, and Retailer (B) is taking the best decision it can, taking into account Supplier's (A) decision. Similarly, a group of players such as retailers and/or suppliers are said to be in Nash Equilibrium if each one is making the best decision it can while taking into consideration the decisions of others.

In order to find the solution of a non-cooperative game, the payoff matrix of the game needs to be determined. Once the payoff matrix is determined, the next step is carrying out Nash equilibrium analysis. Before determining the payoff matrix, payoff functions needs to be developed.

The notations used to derive the payoff functions and subsequent payoff matrixes are shown below.

Notations

$\boldsymbol{\pi}$: payoff of the supply chain collaboration at different modes; $\boldsymbol{\pi_N}$ represents the expected Payoff at "No - Collaboration Mode"; $\boldsymbol{\pi_P}$ represents the expected Payoff at "Partial Collaboration Mode"; $\boldsymbol{\pi_F}$ represents the expected Payoff at "Full Collaboration" mode.

I_c: $I =$ Inventory carrying cost
T_c: $T =$Transportation cost
P_c: $P =$Production fixed cost for the supplier
A_c: $A =$ Administration cost
Q: Q =Quanitity of items sold
W_u: W =Unit selling price of the supplier
U_c: U = Unit production cost of the supplier
R_e: R = Expected Revenue of the supplier
P_e: P = Expected Profit of the supplier
M_c: $M =$ Implementation cost
O_c: $O =$ Operational cost O_c
S_c: $S =$ Partnership opportunity cost
K_c:K= Fixed ordering cost (everytime retailer places an order)
H_c:H= Expected inventory holding cost for the retailer
Q_c = Q= Quantity of items sold
p_c= p= Selling price
c_c=c= Cost price
S_x = System implementation and integration cost
P_i = Partnership instability cost
T_w= Switching cost

ΔC =

$$\begin{cases} \Delta \mathbf{C_{PR}} & \textbf{Additional costs to be incurred by the retailer in case of swticing to Partial Collaboration Mode} \\ \Delta \mathbf{C_{FR}} & \textbf{Additional costs to be incurred by the retailer in case of swticing to Full Collaboration Mode} \\ \Delta \mathbf{C_{PS}} & \textbf{Additional costs to be incurred by the supplier in case of swticing to Partial Collaboration Mode} \\ \Delta \mathbf{C_{FS}} & \textbf{Additional costs to be incurred by the supplier in case of swticing to Full Collaboration Mode} \end{cases}$$

Where

$$\Delta \mathbf{C_{PR}} = (S_{PR} + O_{PR} + P_{PR} + T_{PR})$$
$$\Delta \mathbf{C_{FR}} = (S_{FR} + O_{FR} + P_{FR} + T_{FR})$$
$$\Delta \mathbf{C_{PS}} = (S_{PS} + O_{PS} + P_{PS} + T_{PS})$$
$$\Delta \mathbf{C_{FS}} = (S_{FS} + O_{FS} + P_{FS} + T_{FS})$$

Payoff functions

1. The payoff function PF for supplier in a non-collaboration arrangement with the retailer is given by

$$\boldsymbol{\pi_{SN}} = (p_s - c_s)\, q_s - (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s}) \qquad \textbf{Equation 3.1}$$

2. The payoff function PF for retailer in a non-collaboration arrangement with the supplier is given by

$$\boldsymbol{\pi_{RN}} = (p_r - c_r))\, q_r - (\boldsymbol{K_r} + \boldsymbol{H_r} + \boldsymbol{A_r}) \qquad \textbf{Equation 3.2}$$

3. The payoff function PF for supplier in a partial collaboration arrangement with the retailer is given by

$$\boldsymbol{\pi_{SP}} = (p_s - c_s)\, q_s - (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s} + \Delta \mathbf{C_{PS}}) \qquad \textbf{Equation 3.3}$$

4. The payoff function PF for retailer in partial collaboration arrangement with the supplier is given by

$\boldsymbol{\pi_{RP}}$= $(p_r - c_r)\, q_r - (\, \boldsymbol{P_r} + \boldsymbol{I_r} + \boldsymbol{T_r} + \boldsymbol{A_r} + \Delta \mathrm{C_{PR}}\,)$ **Equation 3.4**

5. The payoff function PF for supplier in a full collaboration arrangement with the retailer is given by

$\boldsymbol{\pi_{SF}}$= $(p_s - c_s)\, q_s \; - \{\, (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s}) + \Delta \mathrm{C_{FS}} /2\}$ **Equation 3.5**

6. The payoff functions PF for retailer in a full collaboration arrangement with the supplier is given by

$\boldsymbol{\pi_{RF}}$ = $(p_r - c_r)\, q_r \; - \{\, (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s}) + \Delta \mathrm{C_{FR}} /2\}$ **Equation 3.6**

Payoff Matrix

The next step after determining payoff functions is to transform them into a payoff matrix as shown below in table 9.

Table 9: Payoff Matrix

Supplier (s)

Retailer (s)

	Full Collaboration	**Partial Collaboration**	**Non-Collaboration**
Full Collaboration	π_{RF} , π_{SF}	π_{RF} , π_{SP}	π_{RF} , π_{SN}
Partial Collaboration	π_{RP} , π_{SF}	π_{RP} , π_{SP}	π_{RP} , π_{SN}
Non- Collaboration	π_{RN} , π_{SF}	π_{RN} , π_{SP}	π_{RN} , π_{SN}

The retailers' three possible strategies—full collaboration, partial collaboration, or no collaboration—form the rows of the matrix. Similarly, the suppliers' three possible strategies—full collaboration, partial collaboration and no collaboration —form the columns of the matrix. Each cell of the matric represents the players' payoffs under different strategies. For each outcome, row's payoff i.e. retailers' payoff is always listed first, followed by column's payoff i.e. suppliers' payoff.

For instance, the upper left hand corner above depicts that when a retailer or a group of retailers forms "full collaboration" partnership with a supplier or a group of suppliers, the retailer or the group of retailers gets a payoff of π_{RF} and the supplier or a group of suppliers gets a payoff of π_{SF}.

3.3.2.2 Nash equilibrium analysis

The game between retailer(s) and/or supplier(s) can have multiple Nash equilibriums depending on the payoff functions. Some of the possible Nash equilibriums are as follows:

By examining the possible pairs of actions, we observe that (Partial Collaboration, Full Collaboration) and (Partial Collaboration, Partial Collaboration) could be one of the Nash equilibriums under certain conditions.

1. (Partial Collaboration, Full Collaboration)

The action pair (Partial Collaboration, Full Collaboration) is a Nash Equilibrium because (i) given player 2 i.e. the supplier chooses full collaboration, player 1 i.e. retailer is better off choosing partial collaboration rather than "full collaboration" or "no collaboration". The strategy

(Full Collaboration, Partial Collaboration) is a pure Nash strategy which could exist when the following equations are being satisfied:

$$(S_{PS} + O_{PS} + P_{PS} + T_{PS}) > (S_{FS} + O_{FS} + P_{FS} + T_{FS}) \qquad \textbf{Equation A}$$

$$(S_{FR} + O_{FR} + P_{FR} + T_{FR}) > (S_{PR} + O_{PR} + P_{PR} + T_{PR}) \qquad \textbf{Equation B}$$

Equation A indicates that when the additional costs required for the supplier to switch to partial collaboration mode are higher than switching to full collaboration mode, the dominant strategy for the supplier would be to go for full collaboration. Given player 2 goes with full collaboration, the expected additional costs of the retailer at the full collaboration mode are higher than at the partial collaboration mode. So, the dominant strategy for the retailer would be to go with partial collaboration.

Additionally, when the above equations are being met, the retailer's expected payoff is likely to be higher in partial collaboration mode than that in "full collaboration" or "no collaboration" mode. This is because in full collaboration, the administration costs, inventory costs, transportation costs and production costs are to be shared equally between the supplier and the retailer. Therefore ΔC_R i.e total costs involved in switching to full collaboration are likely to be higher as compared to partial collaboration or no collaboration mode. In partial collaboration, all major costs like production, inventory, and transportation are to be endured by the supplier. In no collaboration, it is likely that the inventory costs and transportation costs are likely to be more than in either of the other two strategies i.e. full collaboration and partial collaboration.

(ii) given that the player 1 i.e. retailer chooses partial collaboration, player 2 i.e. supplier is better off choosing full collaboration than partial collaboration because the additional costs required for the supplier to switch to partial collaboration mode are higher than switching to full collaboration mode as depicted in equation A. Apart from total switching costs, all other major costs such as inventory, production, transportation and administration costs are to be endured alone by the supplier. The supplier will own the inventory until it is sold by the retailer. Therefore, there are substantial risks involved for the supplier.

Full collaboration might not be in the best interest of the retailer because any inefficiency from the supplier's part might prove to be costly for the retailer since the total costs are to be shared between the two entities. The retailer has no control over some of the costs like "production costs", inventory costs" and "transportation costs". Yet the retailer has to share these costs along with the supplier. The inventory costs are substantial and the inventory policies are likely to be taken by the supplier rather than the retailer in full collaboration mode. However, in partial collaboration, inventory costs, transportation costs and administration costs are full endured by the supplier alone rather than the retailer. In this situation, the retailer is better off since major costs are met by the supplier. But in partial collaboration, the retailer might not get the massive discounts as in the case of the full collaboration. In partial collaboration, the total cost increases at the supplier's end but these costs can be offset by charging more from the retailer. In case of increasing the prices of goods from the retailers', this will result in retailer charging more from the end customer. As a result, the demand for the products can diminish which, in turn, can lead to the retailer ordering fewer quantities of goods. As a result, the total supply chain profit i.e. net profit earned by the retailer and supplier might be less than in case of a full collaboration.

2. (Partial Collaboration, Partial Collaboration)

The second action pair (partial collaboration, partial collaboration) is a Nash equilibrium because (i) given player 2 i.e. the supplier chooses partial collaboration, player 1 i.e. retailer is better off choosing partial collaboration rather than "full collaboration" or "no collaboration". In partial collaboration, the below mentioned condition applies:

$$(S_{PS} + O_{PS} + P_{PS} + T_{PS}) < (S_{FS} + O_{FS} + P_{FS} + T_{FS}) \quad \textbf{Equation C}$$

$$(S_{FR} + O_{FR} + P_{FR} + T_{FR}) < (S_{PR} + O_{PR} + P_{PR} + T_{PR}) \quad \textbf{Equation D}$$

Equation C indicates that when the additional costs required for the supplier to switch to partial collaboration mode are lower than switching to full collaboration mode, the dominant strategy for the supplier would be to go for partial collaboration strategy. Given that supplier goes with partial collaboration, the expected additional costs of the retailer at the full collaboration mode are higher than at the partial collaboration mode. So, the dominant strategy for the retailer would be to also go with partial collaboration with the supplier.

Moreover, the retailer's expected payoff is likely to be higher in partial collaboration mode than that in "full collaboration" or "no collaboration" mode. This is because in partial collaboration, the supplier is able to control the lead time component of order point better than a customer with thousands of suppliers they have to deal with. In partial collaboration, the supplier takes on a greater responsibility to have the products available when needed, therefore lowering the need for safety stock for the retailer. The retailer also doesn't need to operate a warehouse since the ownership of the inventory gets completely transferred to the supplier which results in substantial inventory cost savings. Apart from that the supplier also keeps track of inventory movement and takes over responsibility of product availability resulting in reduction of stock outs, there-by increasing end customer satisfaction. This also helps the retailer to curtail costs on the forecasting and the purchasing activities since it becomes the responsibility of the supplier to do forecasting. As a consequence of that, the retailer is likely to see increase in sales owing to less stock out situations as customers will find the right product at right time. It also decreases administrative costs because the supplier takes on most of the responsibility of restocking and calculation order point which ultimately helps purchasing department to spend less time issuing and reconciling purchase orders.

(ii) Given that the player 1 i.e. retailer chooses partial collaboration, player 2 i.e. supplier is better off choosing partial collaboration than full collaboration or no collaboration strategy. This is because in partial collaboration, the additional costs of switching to partial collaboration mode are less than the costs for switching to full collaboration mode as shown in equation C. Moreover, in this mode, suppliers are in better position to ascertain how the retailer is going to place the orders. In partial collaboration, usually, the retailer sends the point of sale (POS) data directly to the supplier, which in turn, improves the visibility and results in better forecasting. Even though the supplier takes on the responsibility for replenishment, the savings in operating costs alone can easily offset the costs of going into partial collaboration. As a result of going into partial collaboration, the supplier can achieve tactical cost savings which includes reduced administrative and operating costs due to fewer order problems caused by bad data. Apart from tactical cost savings, supplier can also achieve strategic operating cost savings in the form of reduced finished goods inventory requirements owing to reduced demand variability, better forecasts, and better information for Sales & Operations Planning (S&OP).

3.3.3 Collaboration model development

When the partners enter into collaboration, wide range of costs is incurred. ΔC_{PR} and ΔC_{FR} represents the additional costs that will be incurred to the retailer as a result of entering into partial collaboration and full collaboration modes respectively with the supplier.

Similarly, ΔC_{PS} and ΔC_{FS} represents the additional costs that will be incurred to the supplier as a result of switching into partial collaboration and full collaboration modes respectively with the retailer.

These additional costs have four components as mentioned previously in section 3.3.2. The details about these cost components are as follows:

S_{xx} represents cost of system implementation and integration costs, coordinating and integrating business process among partners, and translating and integrating data among systems.

O_{xx} represents the operational cost of running collaborative systems. This includes salaries of additional personnel to be hired specifically for running and maintaining collaborative systems and costs incurred as a result of operating those collaborative systems.

P_{xx} denotes the value of the benefits missed out by not implementing a more beneficial partnership (Gibbons, 1995). In other words, it is the cost incurred by not exploiting the advantage that would be had by adopting a more productive relationship with the partner.

T_{xx} signifies costs of switching partners. The costs are considerably high as a result of switching partners. For instance, inflexible systems such as EDI involves high costs for switching to other partners which leads to greater partnership opportunity cost (Poirier & Bauer, 2001).

Therefore, when partners are faced with the decision of choosing between non-cooperative and cooperative strategies, ΔC_{PR}, ΔC_{FR}, ΔC_{PS}, ΔC_{FS} , which denote the additional costs to be borne individually by each retailer and the supplier in case of switching to partial collaboration or full collaboration mode respectively, are crucial during the decision making process of collaboration. Great emphasis is placed by the partners on these costs when deciding about entering into partnership with each other or not. In case the additional costs to be entailed in cooperative relationships are higher than that of non-cooperative relationship, the firm's preferred choice would be to opt for no collaboration strategy.

In collaborative supply chain management, low switching costs are preferable for most situations. This is however contrary to Porter's (1985) proposition that high switching costs are necessary for stopping partners from leaving coalition. Since various studies have revealed that partnerships that are sustained through coercion, threats or high switching costs fail to give the equity of benefits to partners which are required to ensuring successful collaboration (Kumar & Dissel, 1996; Iacovou *et al*.,1995).

Keeping in view of the recommendations by Kumar & Dissel (1996) and Iacovou *et al*. (1995), the decisions regarding collaboration mode are based on low switching costs. Therefore, each of S_{xx} , O_{xx} , P_{xx} , T_{xx} costs are compared from the perspective of each partner, and the final decision regarding which type of collaboration will best suit an individual partner is based on that comparison.

Other costs such inventory carrying costs, transportation costs and production fixed costs etc. are important too but are not the main focus during the decision making process. However after entering into collaboration, partners can stress each other to restructure the supply chain processes and operation systems so that reductions can be made in the inventory carrying costs and other related costs since the costs in partial or full collaboration are to be shared equally by the partners.

After application of ANP method, potential partners are shortlisted and are further scrutinized by comparing S_{xx} , O_{xx} , P_{xx} , T_{xx}. The concept of game theory is applied not only to ascertain likely responses of partners but also to determine which mode of collaboration will best suit each partner. S_{xx} , O_{xx} , P_{xx} , T_{xx} costs are of great importance for partners when deciding about which collaboration to select.

In order to help prospective partners make the decision regarding which type of collaboration will be beneficial for them, a collaboration decision making model was built using C++ language. The complete program is attached in appendix B.

3.3.3.1 Model formulation

The model can be used for four different types of collaboration scenarios as shown below:

Different collaboration scenarios:

Scenario 1:

Single supplier ($n_s = 1$) collaborates with a single retailer ($n_r = 1$).

Scenario 2:

A group of retailers ($n_r > 1$) contemplating about collaborating with a single supplier ($n_s = 1$).

Scenario 3:

A group of suppliers ($n_s > 1$) contemplating about collaborating with a single retailer ($n_s = 1$).

Scenario 4:

A group of suppliers ($n_s > 1$) contemplating about collaborating with a group of retailers ($n_r > 1$).

Method

A program in C++ is written which basically takes S_{xx} , O_{xx} , P_{xx} , T_{xx} as an input from each partner and then sums up the four cost components of these costs for each mode of collaboration. Finally, it makes recommendations to each partner about which mode of collaboration will be best for it. For instance, if full collaboration is expected to be benefiting both the supplier and retailer; however the total switching costs for retailer is lower in full collaboration and higher for supplier. In this case, supplier would not necessarily opt for full collaboration with the retailer since supplier is required to spend more than the retailer in partial collaboration. Negotiations can certainly take place between retailer and supplier but supplier's expected decision would be "no". May be partial collaboration or no collaboration is more beneficial to supplier since it entails low switching costs than that in full collaboration. However, if expected benefits for supplier in partial collaboration are higher than the other two types of collaboration; in this case, the supplier would not care about high switching costs and will enter into partial collaboration with the retailer. The C++ program is built upon the foundation of Nash equilibrium.

Input

The user (supplier or retailer) will be prompted to enter the following cost information as shown below:

S_{xx} = System implementation and integration cost

O_{xx} = Operational cost

P_{xx} = Partnership instability cost

T_{xx}= Switching cost

Process

After taking the above mentioned costs as inputs, the program will actually sum up four cost components for each partner under each collaboration mode and recommend which mode of collaboration will best each partner. Mode of collaboration that involves low total switching costs will be the preferred choice.

Output

As mentioned earlier, a partner can have three choices to make i.e. "Partial Collaboration" "Full Collaboration" or "No Collaboration". The decision criteria whether to go for any of the above mentioned collaboration categories will solely depend on S_{xx} , O_{xx} , P_{xx} , T_{xx} costs. The final output will be in the following format as shown in figure 9 below:

Example Output for scenario 2

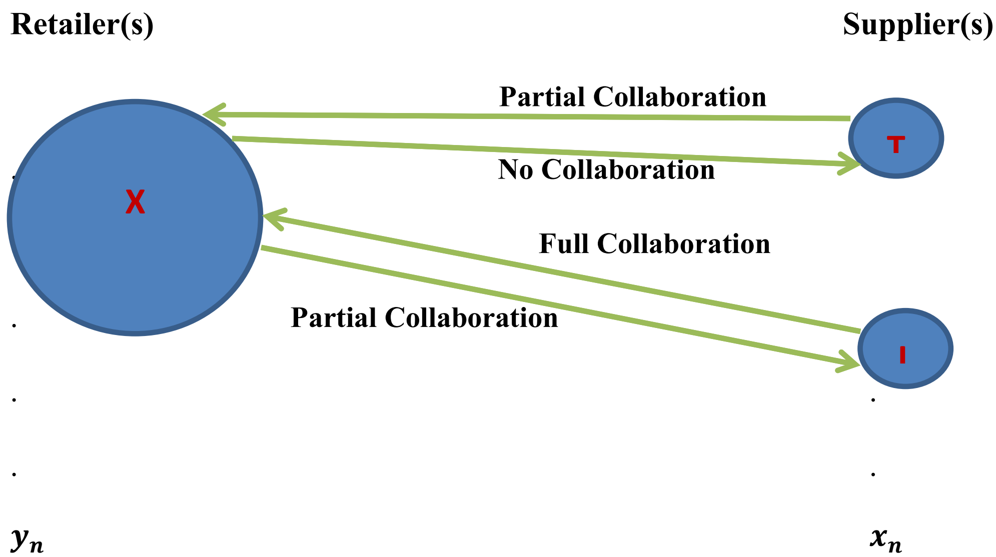

Figure 9: Sample output of the model

The output shows that for retailer X, the best strategy for collaboration would be to form no collaboration and partial collaboration with suppliers T and I respectively. Similarly, the best strategies for suppliers T and I would be to form partial collaboration and full collaboration with retailer X.

3.4 Profit allocation mechanism using Shapely method

The last step in in the process of partner selection for supply chain collaboration is developing a profit allocation mechanism via Shapley method. Profit allocation amongst the prospective partners is designed as a cooperative game since a coalition between a supplier and the retailer has already been formed and each has its own payoff function. Shapely value is a solution model in cooperative game theory. Assuming that a coalition of players collaborates, and attains a specific overall gain from that collaboration; as some players might contribute more to the alliance than others or may have different bargaining power, Shapley value allocates profit according to the "adding value" each partner brings for the alliance. This ensures that partners are rewarding corresponding to their contribution in the coalition (Ferguson, 1998).

In our study, it is assumed that in partial collaboration, each partner has complete control over pricing decisions. For instance, the payoff payoff function for retailer in partial collaboration arrangement with the supplier is represented by

$$\pi_{RP} = (p_r - c_r)\, q_r - (\, I_r + T_r + A_r + \Delta \mathrm{C}_{\mathrm{PR}}\,)$$

In the equation, p_r, c_r q_r represents the retaile price, wholeslae price and the number of items sold to the end customers respectively by the retailer. In partial collaboration, the retailer is free to set pricing on its own. However, suppliers expect retailers to set resonable prices since suppliers are bound to re-buy the unsold inventory from the retailer. Usually, a supplier sets a limit for re-buying the unsold inventory. Therefore, it is in the best interest of the parties to charge a resonable price from the end customers. Inventory costs, transportation costs and adminsitrative costs are shared between the retailer and the supplier. However,total switching costs are endured separately by the partners in partial collabration.

Similarly, the payoff function for supplier in partial collaboration arrangement with the retailer is represented by

$$\pi_{SP} = \; (p_s - c_s)\, q_s - (\, I_s + T_s + A_s + P_s + H_s + \Delta \mathrm{C}_{\mathrm{PS}})$$

p_s, c_s, q_s denotes the retaile price, cost price and the total number of items sold to the retailer respectively.

In partial collaboration, the supplier is also free to make pricing decisions on its own.

However, in case of full collaboration, the partners work like a single entity. The pricing decisions are made individually by each partner like in partial collaboration. However, the total switching costs are shared equally among the partners. In full collaboration, there is a possibility of retailer paying more total switching costs than the supplier or vice versa. This is the essence of full collaboration. Full collaboration promotes the culture of trust and commitment. Retailer normally gets heavily discounted prices from the supplier. As a result, the retailer will be in a better position to sell the goods at a reduced price to end customers, which in turn, would increase demand from the customers and ultimately give both retailer and the supplier a completive edge from their rivals as a result of selling more goods at an affordable price. This is the main reason why most retailers and supplier enter into collaboration. In full collaboration supplier is able to reduce its operating costs as a result of better forecasts, reduced demand variability and better information for sales & operations planning (S&OP).

When calculating the final payoff functions for the partners, Shapely value is interpreted in terms of expected marginal contribution. Marginal contribution can easily be determined by taking into account all the possible orders of the players entering the coalition. The amount a player receives through this method is dependent on the order in which the players join the coalition. Shapley value is an average payoff to the players provided players are entered in entirely random order (Ferguson, 1998). Shapely Value method ensures that partners who contribute more to the coalition should be paid more and vice versa. The determination of shapely value is based on certain assumptions as follows:

It is assumed that N is a set of players $S \in N$ is a subset of N and *V(s)* is expressed as the characteristic function of the subset. s denotes the income and we set Φ_1 as profit of i involved in the coalition and then it is assumed that if fulfills the following conditions:

$\sum_{i=1}^{s} \Phi_i = v\ (s)$ $\qquad\qquad$ $v\ (s) > \sum_{i \in s} v\ (i)$

Based on shapely theory, it can get:

$\Phi_i = \sum_{s \in s_i} \omega\ (|s|)\ \ [v(s) - v\ (s \backslash\ i)]$

$$\omega\ (|s|) = \frac{(n - (|s|)!\ (|s| - 1)!}{n!}$$ **Equation 3.7**

In the formula above, $\omega\ (|s|)$ is a weighted factor, $|s|$ denotes the size of the subset, i.e. the number of participants; s_i are all subset that entails *I* in the set of *s*, $v\ (s \backslash\ i)$ of $[v(s) - v\ (s \backslash\ i)]$ represents the income after eliminating *i* from subset s. so $[v(s) - v\ (s \backslash\ i)]$ can be considered as member *i* contributing to the coalition of *s*.

Ferguson (1998) interprets the formula as follows: suppose a random order of players is chosen with all *n*! orders (permutations) of the players equally likely. Next, the players are entered according to this order. In case, when player *i* enter, he creates coalition (which means if the player finds $s - \{i\}$ there already), he obtains the amount $[v(s) - v\ (s - \{i\})]$.

The probability that when *i* arrives, he will find coalition $s - \{i\}$ there already is $(|s| - 1)!\ (n - |s|)!/n!$. Denominator represents the total number of permutations of the *n* players in the coalition. Numerator denotes the number of these permutations in which the $n - |s|$ participants of $s - \{i\}$ come first $(|s| - 1)!$ ways, next player *i* and then the remaining $n - |s|$ players $((n-|s|)!$ ways). As a result, $\Phi_i\ (v)$ represents the average amount player *I* contributes to the overall coalition provided players serially form this coalition in a random order (Ferguson, 1998).

Chapter 4:

Numerical Application

4.1 Introduction

In this chapter, we present a numerical application of the proposed approach to investigate the following research questions:

1) How supplier profiling can be carried out to build a list of suppliers that conforms to certain minimum criteria?
2) How to solve the multi-criteria partner selection problem for collaboration? How to solve relationships among some critical variables?
3) What choices suppliers and retailers have? What kind of collaboration will best suit a particular partner? In other words, under what conditions are suppliers and retailer willing to collaborate?
4) After collaboration, how the profit will be allocated fairly amongst the partners to ensure long term collaboration?

4.2 Case illustration

Taylor Sons (hypothetical organization) has decided to open its new outlet in Montreal. Taylor Sons is one of the Quebec's largest regional retailers in food and beverage industry. It is an expensive brand with revenues exceeding $500 million. Some of Taylor's products include dairy products, confectionery, bottled water baby food, pet foods coffee breakfast cereals, and ice cream. The Chief Manager of the new outlet has been given the task to search for new appropriate suppliers who can offer quality goods at an affordable price. Supplier selection is a daunting task for any firm and it requires intense planning to develop a framework which ensures prospective suppliers will be able to conform to their particular set of requirements.

4.3 Problem

The Chief Manager is aware of other retailers' market positions. His vision for this new outlet is to increase its competiveness against both local and foreign competitors operating in food and beverage industry in Montreal. The Chief Manager believes that the best way forward in accomplishing this goal is to move beyond "arm's-length" relationships with its prospective suppliers to "long-term collaborative" ones. He is fully aware of the advantages which will be realized as a result of going into collaboration with its prospective suppliers.

There are number of local and foreign suppliers available in Montreal region who can cater to the needs of the Taylor Sons. During a research by the Chief Manager, 72% of Montreal's region suppliers were willing to enter into collaboration while 28% rejected the idea.

4.4 Proposed approach

4.4.1 Supplier profiling

Taylor Sons is provided with a list of 1233 potential suppliers. The list contains important information about the potential suppliers such as region, country, market capitalisation and industry type. However, to keep things simple, Taylor Sons considers only three factors: industry type, market capitalisation and location. For analysis, a screen dump below shows the excel sheet containing the list of twenty nine potential suppliers. However, the approach will remain the same for profiling 1233 suppliers.

Table 10: Data Set of Potential Suppliers

No.	Name of Company	Industry Type	Market cap. (Year end, Millions. USD)	Country
1	JBS S.A	1.30	68840.00	5.00
2	A123 Systems, Inc.	1.80	17.00	1.00
3	Aaron's, Inc.	1.60	2290.00	2.00
4	Nestle	1.30	51861.00	5.00
5	Pepsico	1.30	59749.00	5.00
6	Unilever	1.30	3922.00	6.00
7	Accenture Plc	1.70	45908.00	4.00
8	Accretive Health, Inc.	1.80	1263.00	2.00
9	ACE Limited	1.70	28764.00	3.00
10	Acme Packet, Inc.	1.10	1601.00	4.00
11	Procter & Gamble	1.30	10952.00	5.00
12	Activision Blizzard, Inc.	1.30	12584.00	6.00
13	Adobe Systems Inc.	1.40	19078.00	9.00
14	ADTRAN Inc.	1.40	1275.00	5.00
15	Advance Auto Parts Inc.	1.60	5451.00	5.00
16	Advanced Micro Devices, Inc.	1.80	1943.00	5.00
17	Advantage Oil & Gas Ltd.	1.10	535.00	5.00
18	General Mills	1.30	2732.00	5.00
19	Kraft	1.30	657.00	8.00
20	BRF	1.30	1044.00	6.00
21	Aetna Inc.	1.20	16264.00	9.00
22	Affiliated Managers Group Inc.	1.40	7672.00	1.00
23	Aflac Inc.	1.70	24913.00	2.00
24	Dole Food Company	1.30	5028.00	5.00
25	Bunge Limited	1.30	880.00	5.00
26	Agilent Technologies Inc.	1.20	15413.00	5.00
27	Sysco Corporation	1.30	4846.00	5.00
28	Agnico-Eagle Mines Ltd.	1.20	8463.00	9.00
29	Grupo Bimbo	1.30	16535.00	5.00

The two tables shown below represent the numeric values assigned to the industry type and country respectively.

Table 12: Numeric value for region

No.	Industry Type	Numeric Value
1	Automobiles	1.1
2	Aerospace & Defense	1.2
3	Food & Beverage	1.3
4	Machinery/Industrial Goods	1.4
5	Pharmaceutical	1.5
6	Telecommunication	1.6
7	Logistics	1.7
8	Retails	1.8
9	Logistics	1.9

Table 11: Numeric value for industry

No.	Region	Numeric Value
1	Africa	1
2	Asia	2
3	Central Asia	3
4	South East Asia	4
5	North America	5
6	South America	6
7	Middle East	7
8	Europe	8
9	Australasia	9

Table 13: Cluster analysis result

No.	Name of Company	Industry Type	Market cap. (year end, mln. USD)	Country	Cluster Number
1	Unilever	1.3	3,922	6	1
2	Acme Packet, Inc.	1.1	1,601	4	1
3	Procter & Gamble	1.3	10,952	5	1
4	Activision Blizzard, Inc.	1.3	12,584	6	1
5	Adobe Systems Inc.	1.4	19,078	9	1
6	ADTRAN Inc.	1.4	1,275	5	1
7	Advantage Oil & Gas Ltd.	1.1	535	5	1
8	General Mills	1.3	2,732	5	1
9	Kraft	1.3	657	8	1
10	BRF	1.3	1,044	6	1
11	Aetna Inc.	1.2	16,264	9	1
12	Dole Food Company	1.3	5,028	5	1
13	Bunge Limited	1.3	880	5	1
14	Agilent Technologies Inc.	1.2	15,413	5	1
15	Sysco Corporation	1.3	4,846	5	1
16	Agnico-Eagle Mines Ltd.	1.2	8,463	9	1
17	Grupo Bimbo	1.3	16,535	5	2
18	JBS S.A	1.3	68,840	5	2
19	Nestle	1.3	51,861	5	2
20	Pepsico	1.3	59,749	5	3
21	A123 Systems, Inc.	1.8	17	1	3
22	Aaron's, Inc.	1.6	2,290	2	3
23	Accenture plc	1.7	45,908	4	3
24	Accretive Health, Inc.	1.8	1,263	2	3
25	ACE Limited	1.7	28,764	3	3
26	Advance Auto Parts Inc.	1.6	5,451	5	3
27	Advanced Micro Devices, Inc.	1.8	1,943	5	3
28	Affiliated Managers Group Inc.	1.4	7,672	1	3
29	Aflac Inc.	1.7	24,913	2	3
		1.271	7165.235	6.00	Cluster 1 average
		1.300	60150.000	5.00	Cluster 2 average
		1.678	13135.667	2.78	Cluster 3 average
		-0.092	-0.506	0.23	Cluster 1 weighted average (%)
		-0.071	3.148	0.02	Cluster 2 weighted average (%)
		0.198	-0.094	-0.43	Cluster 3 weighted average (%)
		1.100	535.000	4.00	Cluster 1 minimum
		1.300	51861.000	5.00	Cluster 2 minimum
		1.400	17.000	1.00	Cluster 3 minimum
		1.400	19078.000	9.00	Cluster 1 maximum
		1.300	68840.000	5.00	Cluster 2 maximum
		1.800	45908.000	5.00	Cluster 3 maximum
				0.59	Cluster 1 weight (%)
				0.10	Cluster 2 weight (%)
				0.31	Cluster 3 weight (%)

Supplier profiling is carried out through process of cluster analysis as shown in table 13.

NeuroXL, an add-on Microsoft Excel, is used to perform cluster analysis on the spreadsheet.

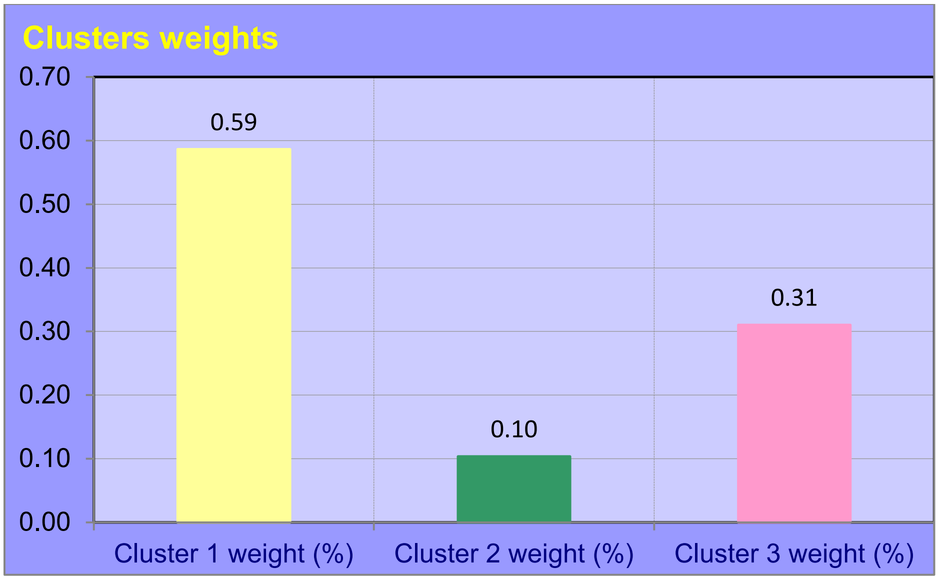

Figure 10: Cluster Weights

The result of cluster analysis groups the companies into three different categories. The average data values for these categories and the weight of each cluster, which denotes the percentage of items belonging to the cluster, are shown in figure 10. A graphical representation of each cluster can be created from the data above:

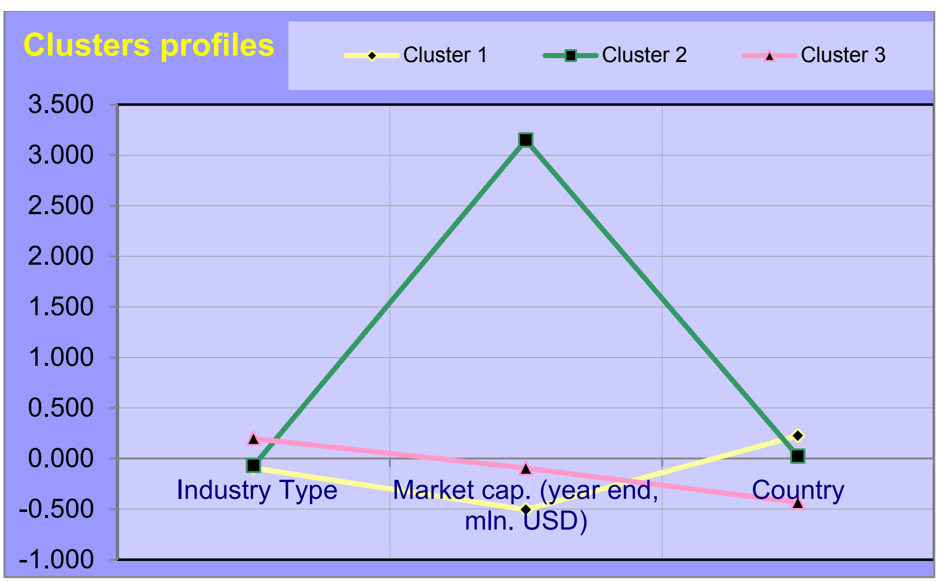

Figure 11: Cluster Profiles

From figure 11, we can ascertain the characteristics of each cluster. For instance, cluster 2 contains companies which belong to food and beverage industry, located in North America and have high market capitalization.

Through implementation of above mentioned steps, supplier profiling can be achieved. Cluster analysis does the work of identifying relevant patterns and trends and then clustering the data into subsequent categories. As a result of supplier profiling through cluster analysis, JBS S.A, Nestle, Pepsico, Unilever, Procter & Gamble, General Mills, Bunge Ltd, Grupo Bimbo, Kraft, and Dole Food company have been shortlisted for further screening through ANP method.

4.4.2 Application of Analytical Network Process

The second step in supplier chain collaboration entails ranking of short listed potential suppliers. Since interdependence relationships exist between the factors and their criterion, the analytical process network (ANP) analysis method is utilized to deal with this kind of relationship. ANP is a multi-criteria decision making method which was presented by Saaty (1996). Through bibliography research, partner selection factors and their criterion, are identified as demonstrated in chapter 3.

In order to structure the decision problem, we first defined the goal, factors, criterion for each factor, and the alternatives. Next, the relations between alternatives, factors and their respective criterions were established. As a result, the network of the problem is built on super decisions software as shown in figure 12.

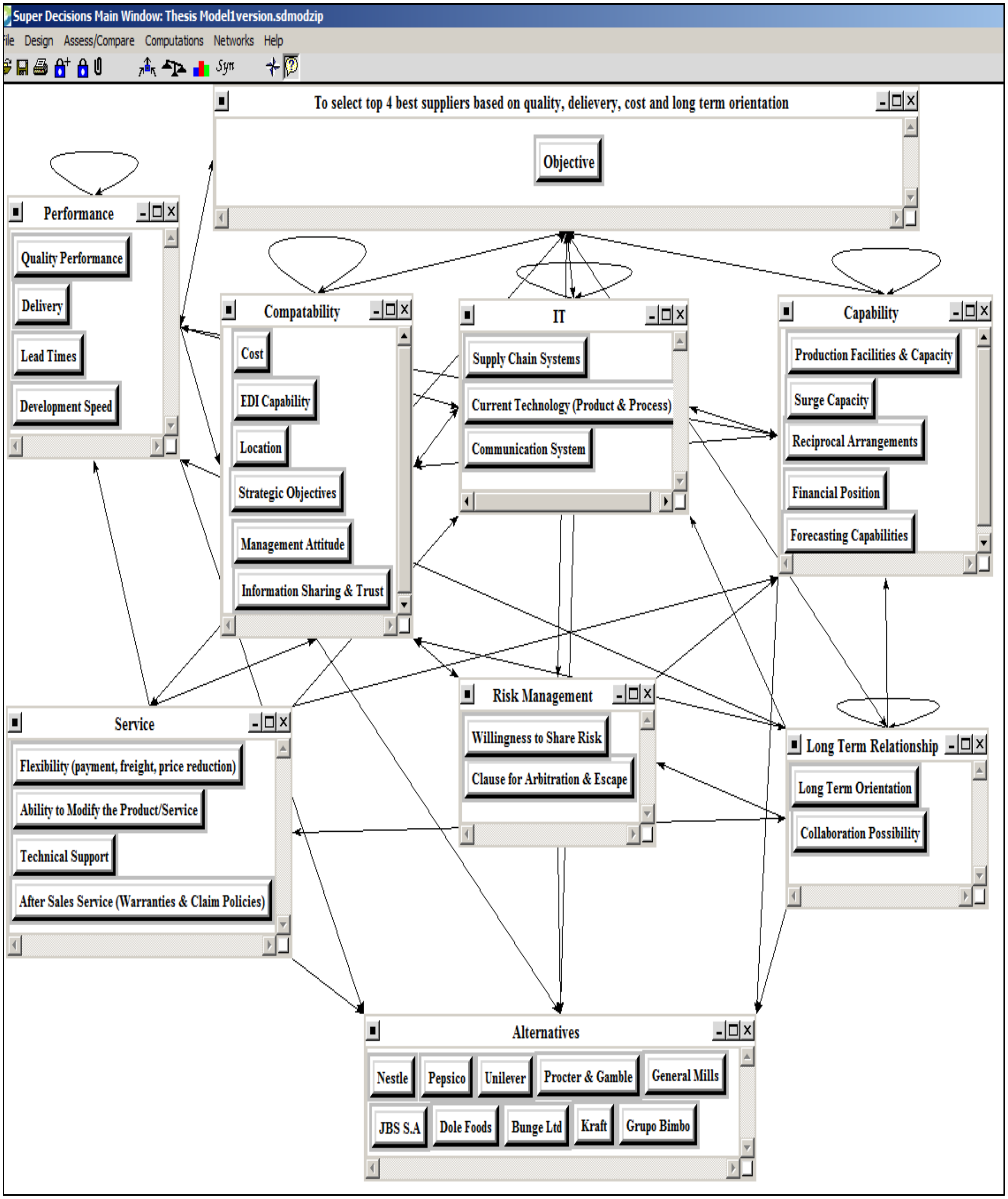

Figure 12: Network model

As can be seen in the network model, ANP method allows dependence relations amongst elements and clusters. Such relations are denoted by arrows, when the dependence occurs between clusters over another cluster. Similarly when there is dependence between elements of the same cluster, it is represented by a loop. In case of an arrow from a cluster to another, it's enough that at least one element of the original cluster is associated to an element of the destination cluster (Saaty, 2005). This way, with possibility to examine dependences among criteria and influence among alternatives, ANP method is applied with the help of Super Decisions software.

Stage 2: Judgments

After structuring of the decision problem along with the identification of the interactions between and within clusters and elements (detailed interactions relationship is explained in chapter 3), the judgment stage begins. In judgment stage, the decision makers express their preferences through creation of the comparison matrices of clusters, elements and ratings, based on Saaty's fundamental scale. The Saaty's fundamental scale is shown below:

Table 14: Scale of Relative Importance

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong or Demonstrated Importance
9	Extreme Importance
2,4,6,8	Intermediate values between adjacent scale values

The comparisons are then made in which an element of a cluster has link of dependency with at least two elements of another cluster. In this way, pairwise comparisons for the elements in each cluster that belong to a parent node are carried out for all the parent nodes in the model. On super decision software, there are several ways to do comparisons: graphic, questionnaire, verbal, matrix. Figure 13 demonstrates an example of pairwise comparison matrix among the elements of the Cluster "compatibility" with respect to element "collaboration possibility". It is apparent that the location has higher influence with a priority of 0.427; followed by cost, with priority 0.23.

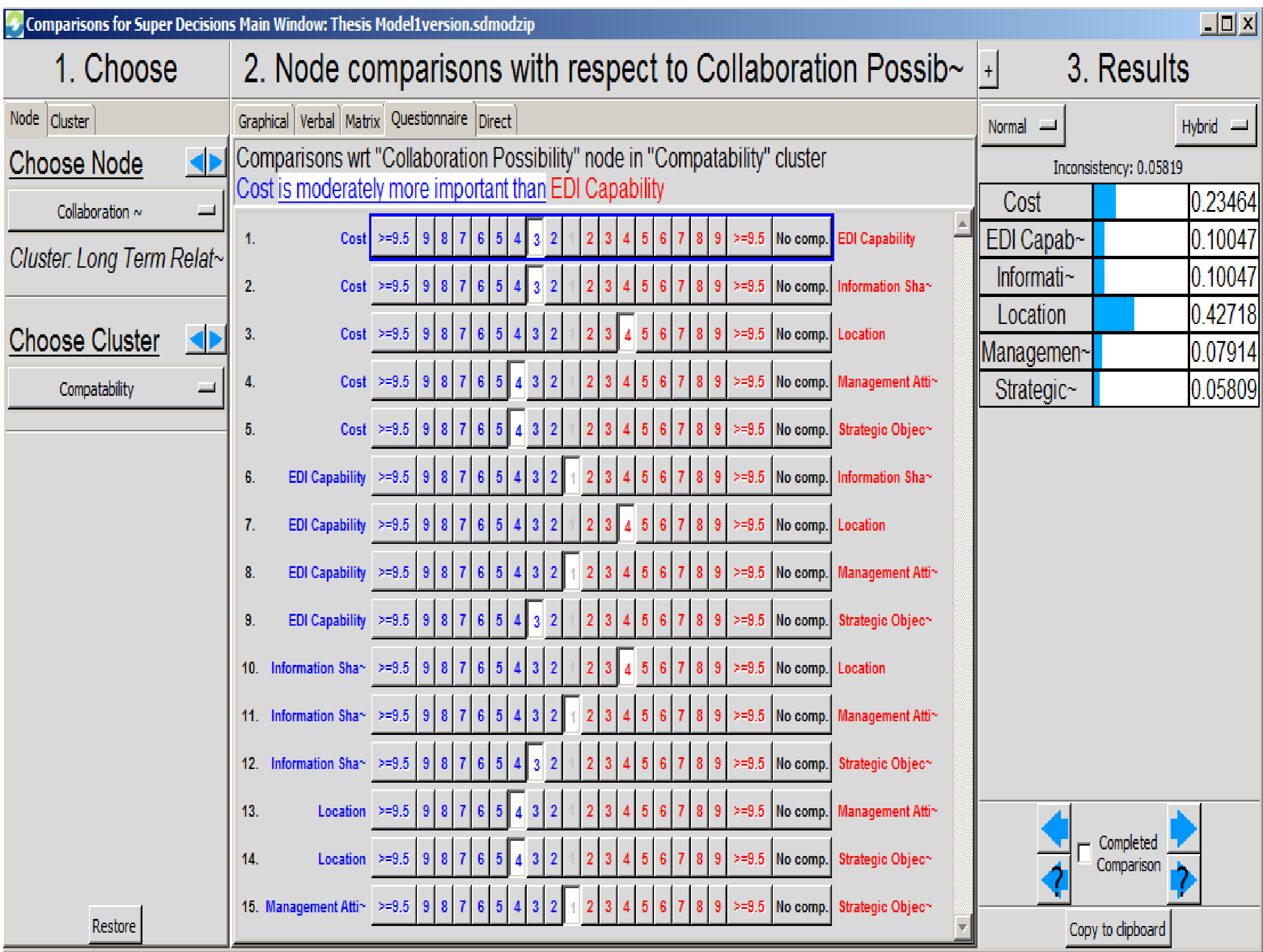

Figure 13: Pairwise comparison matrix between elements of the cluster "Compatibility" with respect to element "Collaboration Possibility"

Table 15: Priorities of element normalized by cluster and priorities from limiting matrix

		Priorities from limiting matrix	Priorities normalized by cluster
Alternatives	Nestle	0.037	0.202
	Pepsico	0.032	0.176
	Unilever	0.023	0.126
	Procter & Gamble	0.018	0.099
	General Mills	0.015	0.084
	JBS S.A	0.014	0.073
	Dole Foods	0.014	0.780
	Bunge Ltd	0.116	0.063
	Kraft	0.009	0.050
	Grupo Bimbo	0.008	0.046
Capability	Financial Position	0.094	0.705
	Forecasting Capabilities	0.010	0.076
	Production Facilities & Capacity	0.021	0.157
	Reciprocal Arrangements	0.003	0.025
	Surge Capacity	0.005	0.004
Compatability	Costs	0.081	0.371
	EDI Capability	0.005	0.022
	Information Sharing & Trust	0.016	0.071
	Location	0.059	0.270
	Management Attitude	0.018	0.086
	Strategic Objectives	0.038	0.176
IT	Communication System	0.020	0.293
	Current Technology (Product & Process)	0.028	0.424
	Supply Chain Systems	0.019	0.281
Long Term Relationship	Collaboration Possibility	0.031	0.481
	Long Term Orientation	0.033	0.518
Performance	Delivery	0.008	0.167
	Development Speed	0.008	0.165
	Lead Times	0.009	0.192
	Quality Performance	0.023	0.475
Risk Management	Clause for Arbitration & Escape	0.011	0.207
	Willingness to Share Risk	0.041	0.792
Service	Ability to Modify Product/Service	0.007	0.028
	After Sales Service (Warranties & Claim Poli	0.009	0.038
	Flexibility (payment,freight, price reduction	0.026	0.111
	Technical Support	0.006	0.026

The local priorities associated with these judgments are shown in table 15. The results of all the pairwise comparisons are inserted in the un-weighted super matrix. The value contained in the cluster matrix are then used to weight the un-weighted super matrix by multiplying the value in (Alternatives, Alternatives) cell of the cluster matrix times the value in each cell in the (Alternatives, Alternatives) part of the un-weighted super matrix to generate the weighted super matrix. Therefore, every part is weighted with its corresponding cluster matrix in this fashion.

Next, the eigenvectors are obtained from the pairwise comparisons of clusters (Clusters Weight matrix). Table 16 below represents the eigenvectors.

Table 16: Eigenvectors Matrix

	Alternatives	Capability	Compatability	IT	Long Term Relationship	Performance	Risk Management	Service	To select top suppliers
Alternatives	0.00	0.17	0.13	0.20	0.11	0.17	0.25	0.14	0.00
Capability	0.00	0.17	0.13	0.20	0.11	0.17	0.25	0.14	0.14
Compatability	0.00	0.17	0.13	0.20	0.11	0.17	0.25	0.14	0.14
IT	0.00	0.17	0.13	0.20	0.11	0.17	0.00	0.14	0.14
Long Term	0.00	0.00	0.13	0.00	0.11	0.00	0.00	0.14	0.14
Performance	0.00	0.17	0.00	0.00	0.11	0.17	0.00	0.14	0.14
Risk Management	0.00	0.00	0.13	0.00	0.11	0.00	0.00	0.00	0.14
Service	0.00	0.00	0.13	0.00	0.11	0.00	0.00	0.00	0.14
To select top suppliers	0.00	0.17	0.13	0.20	0.11	0.17	0.25	0.14	0.00

From table 16, it is possible to identify how much clusters are influenced by another cluster. For example, cluster "capability" influences the clusters "compatibility (0.13), IT (0.2), long term relationship (0.11), performance (0.17), risk management (0.25) and service (0.14). In addition, if there exists an inner dependence (loop) between a cluster such as in clusters "performance", "compatability", "capability", "IT" and "long term relationship"; this indicates how much each cluster gets influenced by itself. For instance, clusters "performance", "compatability", "IT", "capability" and "long term relationship" suffer an influence of themsleves by (0.17), (0.13), (0.20), (0.17) and (0.11) respectively. From the table 16, it can be seen that cluster "service" is only influlenced by clusters "compatability" and "long term relationship". However, cluster “service” influences all clusters except itself and cluster “risk management”. The cluster that have the higher importance is “compatability” based on the weight vectors for the clusters capability, IT, long term, risk management.

Algebraic Development

After the pairwise comparisons, the next step is to determine super matrixes. The un-weighted, weighted and limit matrixes can be found in the CD attached to the thesis.

The unweighted supermatrix is constituted by priority vectors placed in columns, gained as a result of pairwise comparisons. For example, the vector of priority gained in table 15 might be seen in the last column of supermatrix. In each column, the number of prioroities denotes the number of comparisons of the element corresponding to that column.

The weighted supermatrix is worked out by multiplying the weights of the clusters by its corresponding blocks of the unweighted supermatrix. As a result, a stochastic matrix is achieved in which sum of every column is 1. Zeroes in the matrix signify the absence of interaction.

Limit matrix is obtained by increasing the weigted supermatirx to successive powers until its merged together. All priorities are stable. It can be observed that the non-zero values , found in the columns, seem to repeat themselves.

The final ranking of the suppliers is presented in table 17. In the example, the supplier that presents a higher ratio of the ranking is the Nestle, followed by suppliers Pepsico, Unilever, Procter & Gamble, General Mills, Dole Foods, JBS S.A, Bunge Ltd, Kraft and Grupo Bimbo.

In Table 15, priorities of element normalized by cluster and priorities from limiting matrix is shown. Values of "priorities from limiting matrix" column originate from the limit matrix. This basically presents global priority with respect to the integer model, adding 1. These values which are normalized by cluster origin the column "priorities normalized by cluster", in a way that the priorities of each cluster give 1.

The elements "financial position", "cost", "location", and "collaboration possibility" represent the higher priorities in the clusters capability, compatibility, compatibility and long term relationship.

In the cluster "capability", the financial position and production facilities & capacity of the supplier is of utmost importance. Financial stability of the supplier is one of the pre-requisites for long term collaboration since collaboration requires partners to invest in updating systems, share risks and resources. The supplier should have an adequate production facilities and capacity which can allow it to cater to the unexpected demands of the retailer.

In the cluster "capability"; cost, location and strategic objectives of the supplier are important. The retailer expects the supplier to offer them products/goods at an affordable price. Location is also another important aspect. Most retailers prefer suppliers to be located close to their facilities so that their demands can be met in timely fashion. In case if a supplier is far from the retailer, it will incur additional shipment costs. Strategic objectives of the supplier is critical because the suppliers' strategic objectives should align with the retailers' ones. There should be some form of commonality between the partners' strategic objectives.

In "IT" cluster; current technology has a high priority. The supplier must have an updated technological systems and processes in place which can cater to the needs of the collaboration with the retailer.

In "long term relationship" cluster; both collaboration possibility and long term orientation have same importance. It is important for supplier to commit to collaboration with the retailer.

With regards to "performance" cluster, delivery, quality and lead times are important. The retailer expects the supplier to be able to develop and supply a quality product at the right time.

In "risk management" cluster; willingness to share risk has high priority. In collaboration, the retailer expects its partner to fully share the risk.

In cluster "service"; flexibility and ability to modify service/good have higher priorities. The supplier should be able to meet the variation in demand of the retailer and should also be flexible in terms of payments. In case of a change in customer needs, the retailer expects the supplier to be capable of modifying the product/good with ease.

ANP results

Final ranking of the suppliers is shown in table 17 as shown below:

Table 17: The Synthesized Values – the Results for the Alternatives

New synthesis for: Super Decisions Main Window: Thesis Model1ve...

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: Thesis Model1version.sdmodzip

Name	Graphic	Ideals	Normals	Raw
Bunge Ltd		0.311909	0.062922	0.011629
Dole Foods		0.389473	0.078569	0.014521
General Mills		0.414247	0.083567	0.015445
Grupo Bimbo		0.230996	0.046599	0.008613
JBS S.A		0.366485	0.073932	0.013664
Kraft		0.248335	0.050097	0.009259
Nestle		1.000000	0.201732	0.037285
Pepsico		0.871431	0.175796	0.032491
Procter & Gamble		0.494812	0.099820	0.018449
Unilever		0.629378	0.126966	0.023466

Okay Copy Values

As shown in table 17, the "raw" columns denotes the priorities from limiting super matrix, "normals" column represents the results normalized for each component and the column "ideals" present the results gained as a result of dividing the values in either the normalized or limiting columns by the largest value in the column. The number one ranked supplier is supplier Nestle. The top 4 suppliers selected for further screening through game theory includes Nestle, Pepsico, Unilever and Procter & Gamble.

4.4.3 Collaboration model

ANP method helped select four potential suppliers for collaboration. However, it is not yet clear which form of collaboration i.e. "full collaboration", "partial collaboration" or "no collaboration" will best suit the retailer. But, it is not guaranteed that the retailer's decision will be acceptable to the supplier. For example, based on the payoff functions, it might be in the best interest of retailer to go for full collaboration with a particular supplier whereas full collaboration option might not profitable for that particular supplier. In order to address this issue, Nash equilibrium analysis is carried out**.** The collaboration model is built on C++ and it incorporates the concept of Nash equilibrium. The collaboration model can be utilized for different collaboration scenarios as shown below:

Different collaboration scenarios

Scenario 1:

Single Supplier ($n_s = 1$) collaborates with a Single Retailer ($n_r = 1$).

Scenario 2:

A group of retailers ($n_r > 1$) contemplating about collaborating with a single supplier ($n_s = 1$)

Scenario 3:

A group of suppliers ($n_s > 1$) contemplating about collaborating with a single retailer ($n_s = 1$)

Scenario 4:

A group of suppliers ($n_s > 1$) contemplating about collaborating with a group of retailers

($n_r > 1$)

This illustrative example is of scenario 3 type. The program in C++ basically takes S_{xx} , O_{xx} , P_{xx} , T_{xx} as an input both from each partner and then sums up these costs. Finally, it makes recommendations to each partner about which type of collaboration will be best for it. The C++ program is built upon the foundation of Nash Equilibrium.

Input

Four cost components for each partner under each collaboration mode are used as the input for the model.

Table 18: Model input

R1-S1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S1**	Total
F.C	400	400	100	200	F.C 1	1100
P.C	300	250	200	100	P.C 1	850
N.C	0	0	400	550	N.C 1	950
R1-S2	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S2**	Total
F.C	500	400	400	200	F.C 1	1500
P.C	550	200	600	260	P.C 1	1610
N.C	0	0	1100	600	N.C 1	1700
R 1-S3	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S3**	Total
F.C	500	103	250	250	F.C 1	1103
P.C	300	200	250	124	P.C 1	874
N.C	0	0	300	150	N.C 1	450
R1-S4	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R2-S4**	Total
F.C	300	100	150	300	F.C 1	850
P.C	200	150	100	90	P.C 1	540
N.C	0	0	250	100	N.C 1	350

S1-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S1-R1**	Total
F.C	460	110	200	100	F.C 1	870
P.C	220	200	110	100	P.C 1	630
N.C	0	0	340	200	N.C 1	540
S2-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S2-R1**	Total
F.C	600	200	200	200	F.C 1	1200
P.C	600	200	300	150	P.C 1	1250
N.C	0	0	700	650	N.C 1	1350
S3-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S3-R1**	Total
F.C	700	100	100	100	F.C 1	1000
P.C	400	100	140	100	P.C 1	740
N.C	0	0	790	200	N.C 1	990
S4-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S4-R1**	Total
F.C	500	100	220	100	F.C 1	920
P.C	300	100	200	100	P.C 1	700
N.C	0	0	350	400	N.C 1	750

In table 18, retailer 1 (R1) represent "Taylor Sons" and suppliers S1, S2, S3 and S4 represent Nestle, Unilever, Procter & Gamble and Grupo Bimbo respectively.

Method

A program is written in C++ to perform Nash equilibrium analysis for multiple numbers of retailers and/or supplier. In the example, only one retailer and 4 suppliers are considered. A complete program is provided in appendix A.

Table 19: Expected Output

R1-S1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S1**	Total
F.C	400	400	100	200	F.C 1	1100
P.C	300	250	200	100	P.C 1	850
N.C	0	0	400	550	N.C 1	950
R1-S2	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S2**	Total
F.C	500	400	400	200	F.C 1	1500
P.C	550	200	600	260	P.C 1	1610
N.C	0	0	1100	600	N.C 1	1700
R 1-S3	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R1-S3**	Total
F.C	500	103	250	250	F.C 1	1103
P.C	300	200	250	124	P.C 1	874
N.C	0	0	300	150	N.C 1	450
R1-S4	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**R2-S4**	Total
F.C	300	100	150	300	F.C 1	850
P.C	200	150	100	90	P.C 1	540
N.C	0	0	250	100	N.C 1	350
Expected Output						
R1 should do Partial Collaboration with S1						
***R1 should do Full collaboration with S2**						
R1 should do No Collaboration with S3						
R1 should do No Collaboration with S4						

S1-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S1-R1**	Total
F.C	460	110	200	100	F.C 1	870
P.C	220	200	110	100	P.C 1	630
N.C	0	0	340	200	N.C 1	540
S2-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S2-R1**	Total
F.C	600	200	200	200	F.C 1	1200
P.C	600	200	300	150	P.C 1	1250
N.C	0	0	700	650	N.C 1	1350
S3-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S3-R1**	Total
F.C	700	100	100	100	F.C 1	1000
P.C	400	100	140	100	P.C 1	740
N.C	0	0	790	200	N.C 1	990
S4-R1	S_{xx}	O_{xx}	P_{xx}	T_{xx}	**S4-R1**	Total
F.C	500	100	220	100	F.C 1	920
P.C	300	100	200	100	P.C 1	700
N.C	0	0	350	400	N.C 1	750
Expected Output						
S1 should do No Collaboration with R1						
***S2 should do Full Collaboration with R1**						
S3 should do Partial Collaboration with R1						
S4 should do Partial Collaboration with R1						

* Collaboration mode involving minimum payoff (lowest total switching costs) is recommended to each partner.

Since the example is considering only 4 suppliers and one retailer, it is possible to sum and compare the total costs. The likely costs to be incurred by the retailer and the suppliers as a result of going into collaboration are shown in the table 19. For instance, R1-S1 means costs to be incurred by the retailer as a result of going into collaboration with supplier 1. F.C, P.C, and N.C denotes the costs to be entailed by the retailer as a result of collaboration with supplier 1. In this case, R1 should go into "partial collaboration with supplier 1 since the total switching costs (16) is lowest in this mode.

Similarly, S1-R1 means the costs to be endured by supplier 1 as a consequence of going into collaboration with retailer 1. The costs for different collaboration modes are shown in the table 19. In this case, supplier 1 should go into "no collaboration" with retailer. This signifies that it might be profitable for retailer 1 to go into partial collaboration with supplier 1 but supplier 1 will be better off by accepting "no collaboration" option. Therefore, Nash equilibrium is not achieved in this case.

However with regards to R1-S2 and S2-R1, we can see that it is indeed "Nash equilibrium". The Nash equilibrium solution is highlighted black in table 19. Based on the payoff functions, it is recommended that R1 should engage in full collaboration with supplier 2. On the other hand, it is also beneficial for supplier 2 to enter into full collaboration with retailer 1. This is the Nash equilibrium because supplier 2 is making the best decision it can, taking into consideration retailer 1 decision, and retailer 1 is taking the best decision it can, taking into account supplier's 2 decision. Collaboration mode involving lowest payoff denotes that total switching costs required for entering into a particular collaboration mode by the partner will be less. Since, it's already been assumed that collaboration, be it partial or full, will ultimately result in net benefits for a particular partner. Hence, collaboration mode entailing lowest total switching costs will be the preferred choice for the partners. This collaboration model can be used for multiple retailer and/or suppliers.

Output

The input costs are inserted into a text file. The Microsoft Visual studio incorporates the text file. In order to verify and validate the model, input costs as shown in table 18 are included in the text file. The program is run and it gave the following output:

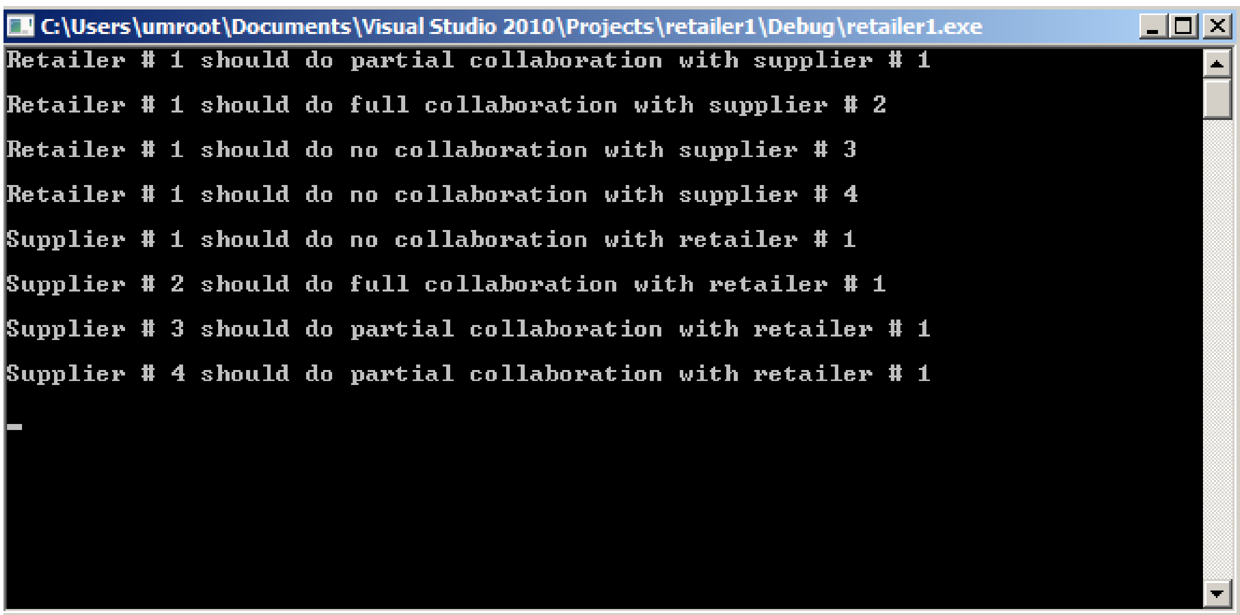

Figure 14: Output from the Model

The output is exactly the same as shown in table 19. In table 19, the results are calculated manually. However, when the program is run, it exactly gives the same results. Finally, supplier 2 i.e. Unilever is selected by the retailer and both intend to enter into full collaboration with each other.

4.4.4 Profit allocation: Shapely value

Next step involves working out a profit allocation mechanism via Shapely value for the partners.

The Shapely value is given by $\Phi_i = (\Phi_1 \ldots\ldots\ldots, \Phi_n)$, where for $i=1, \ldots.n$,

$$\Phi_i = \frac{\sum_{s \in s_i} (|s|) - 1)!\,(n - |s|)!}{n!} [v(s) - v\,(s - \{i\})]$$

The summation as shown in the formula above is basically the summation over all coalitions *s* that include *i*. $[v(s) - v\,(s - \{i\})]$ is an amount by which the value of coalition *s – {i}* rises whenever player *i* joins the coalition game. Therefore, in order to determine, Φ_i *(v)*, we need to list all coalitions that contain *I*, determine the value of player *I*'s contribution to that coalition, multiply this by $(|s| - 1)!\,(n - |s|)!/n!$ and finally, derive the sum. (T. Ferguson, 1998).

The payoff functions were determined in chapter 3. In our fictitious example, partial collaboration has been recommended to both the supplier and the retailer. The payoff functions for partial collaboration for supplier and retailer are shown below:

The payoff function PF for supplier in a full collaboration arrangement with the retailer is given by

$$\boldsymbol{\pi_{SF}} = (p_s - c_s)\, q_s - \{ (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s}) + \Delta \mathbf{C_{FS}} / 2\}$$

The payoff function PF for retailer in partial collaboration arrangement with the supplier is given by

$$\boldsymbol{\pi_{RF}} = (p_r - c_r)\, q_r - \{ (\boldsymbol{I_s} + \boldsymbol{T_s} + \boldsymbol{A_s} + \boldsymbol{P_s} + \boldsymbol{H_s}) + \Delta \mathbf{C_{FR}} / 2\}$$

The costs related to inventory, administration, transportation, total switching costs, in case of partial or full collaboration, and production fixed costs are estimated for each partner. Costs for retailer (R) Taylor Sons and supplier S (Unilever) are shown in table 20.

Table 20: Cost Components

	Inventory Carrying Cost I_x	Transportation Costs T_x	Admisnistration Cost A_x	Production Fixed cost P_x	Total Switching Costs ΔC_x	Total Costs
c(1) R	**150**	**0**	**200**	**0**	**1500**	**1850**
c(2) S	**350**	**90**	**100**	**45**	**1200**	**1785**
c(12) S-R	**400**	**90**	**210**	**45**	**2500**	**3245**

As a result, now we have c ({1}) = 1850, c ({2}) = 1785 and c ({1, 2}) = 3245. Now, there can be two possible orders of arrivals: (1) first retailer then supplier, and (2) first supplier and then retailer.

In case retailer comes before supplier, retailer's contribution is c ({1}) = 1850; when supplier comes the surplus increases from 1850 to c ({1, 2}) = 3245 and as a result, supplier's marginal contribution is c ({1, 2}) – c ({1}) = 3245 – 1850=1395.

In case supplier arrives first before retailer, supplier's contribution is c ({2}) =1785; when retailer comes, the surplus increases from 1785 to c ({1, 2}) = 3245 and as a result, supplier's marginal contribution is c ({1, 2}) – c ({2}) = 3245 – 1785=1460

As a result, a table can be derived as shown below:

Probability	**Order of arrival**	**1's marginal contribution**	**2's marginal contribution**
$\frac{1}{2}$	First retailer then supplier (12)	1850	1395
$\frac{1}{2}$	First supplier then retailer (21)	1460	1785

Figure 15: Marginal Contribution of Players

Therefore, retailer's expected marginal contribution is $\frac{1}{2}$ x 1850 + $\frac{1}{2}$ x 1460 =1655 and supplier's expected marginal contribution is $\frac{1}{2}$ x 1395 + $\frac{1}{2}$ x 1785 = 1590.

Therefore the Shapely values are x_1 =1655 and x_2 = 1590.

The Shapely Values denote that retailer (Taylor Sons) and the supplier (Unilever) need to pay 1665 and 1590 respectively in order to enter into full collaboration with each other.

Chapter 5:

Conclusions & Future Work

6.1 Conclusions

Current economic downturn, intense global competition and fast changing customer demands, have made it difficult for organizations to stay competitive in the current market place. Recession affected customers are constantly looking for better quality and innovative products at a relatively low price. In the nutshell, organizations which are capable of selling products or services which satisfy the above mentioned specifications will be able to dominate the market. In response to this challenge, the concept of supply chain collaboration has emerged as a new approach to attaining competitive advantage through cost reduction, increased asset utilization, and reduced inventories. Collaboration has been seen as important factor for achieving effective and efficient supply chain management. By forming collaboration, firms can help each other to share risks and exploit each other's complementary resources (Park et al 2004). In addition to this, effective long term collaboration can help firms to eliminate excess inventories, increase sales, reduce lead times and improve customer service levels (Anderson & Lee, 1999).

Although, the concept of collaboration has been researched extensively in a wide range of different contexts, apparently few published academic articles and journal papers in supply chain literature have focused on identifying the important steps involved in managing the supply chain collaboration process from its conception through planning and implementation to successful execution. However, this study put into application a combination of different techniques such as cluster analysis, analytical network process and game theory at once and provides a comprehensive analysis on the role each of these technique plays and examines all the necessary steps involved in the process of partner selection for supply chain collaboration.

While supply chain collaboration amongst firms can often provide them with competitive advantage, however, lack of understanding regarding the presence of barriers of collaboration might hamper the advantages of collaboration (Ramesh et al., 2010). A number of factors such as the level of trust between collaborating partners (Delbufalo, 2012), willingness to share information (Barratt, 2004), mistrust regarding the fairness of benefit, costs and risk sharing (Cruijssen, 2012; Rossi, 2012) and availability of adequate and measurement systems to support the efficiency and flexibility requirements of the supply chain (Reddy, 2001a; Karahannas & Jones,1999) can influence the level of benefits that can be realized as a result of collaboration. Therefore, firms must first fully understand the barriers and take appropriate actions to ensure true essence of collaboration is being conformed. Trust is the key factor. The need for trust to exist between partners has been recognized as a vital aspect of collaboration. Information sharing, adequate information technology capabilities and measurements systems are also vital factors that must be considered for ensuring long term collaboration. Collaboration between partners can only happen when all partners can profit from it in one way or the other and provided no partner has anything to gain by changing their own strategy unilaterally.

6.2 SWOT analysis

In order to evaluate the strengths, weaknesses/limitations, opportunities and threats for this study, a SWOT analysis is carried out as shown below:

Strengths

1. Provides comprehensive framework for new firms considering collaboration.
2. Shapely Value method ensures profits are allocated to partners corresponding to their contribution in the coalition.
3. Pre-qualification criteria not only consider partner's financial contribution to the alliance but also take into consideration other important factors such as top management attitude, organizational culture, technical capabilities and long term orientation.
4. The framework in this study for facilitating collaboration between multiple retailers and/or suppliers can be easily tailored and applied to problems in a variety of areas and industries.
5. The collaboration model presented in the study is based on a win-win strategy to ensure that all partners can benefit from it in one way or the other.
6. Nash equilibrium analysis provides a basis for determining the realistic behavior of the partners under different scenarios.
7. Views partner selection for collaboration as a multi-criteria decision making process and includes set of concepts, methods and techniques that aim to facilitate individuals or groups to make decisions that involve various criteria and multiple agents.

Weaknesses/Limitations

1. Through bibliography research, the partner selection factors are chosen mainly from retailers' and suppliers' perspective.
2. The collaboration model takes only total switching costs into account before suggesting the best course of action to prospective partners. The input costs used for the collaboration model are fictional numbers and do not represent real data.

3. In the numerical example, profit allocation via Shapely Value is carried out only for one retailer and four suppliers. However, the method will remain the same for multiple suppliers and/or retailers. Better demonstration could have been provided had there been multiple supplier and/or retailers.

Opportunities

1. The collaboration model can be further developed to include expected benefits to be realized as a result of collaboration. The expected benefits and total switching costs can be used to calculate the net benefits for each of the three types of collaboration.
2. A profit allocation mechanism incorporating the concept of Shapley Value can be modeled on a software program which can quickly work out the Shapely values for multiple partners in a coalition.
3. The approach suggested in the study can be integrated with collaborative planning, forecasting and replenishment (CPFR) approach, which in turn, can be a useful guide for all the stages involved in managing the entire lifecycle of a supply chain collaboration process from its conception through planning and implementation, to successful execution and disposal.

Threats

1. In case the total switching costs are not calculated or documented accurately, the model would fail to find correct Nash Equilibrium solution, which in turn, can result in partners' not collaborating when in fact they should be.
2. The partners' can deliberately inflate the switching costs and other relevant costs such as inventory holding costs, transportation, administration and production fixed costs so as to

get the maximum profit out of the coalition. The profit allocation mechanism developed through Shapely value assumes that partners are being honest and the costs truly reflect their contribution in the coalition.

6.3 Future work

In future, the framework suggested in the study can be further developed by integrating collaborative planning, forecasting and replenishment (CPFR) method. Shapley Value method can be modeled on a software program so that shapely values can be easily estimated for multiple partners in a particular coalition. A detailed mechanism regarding estimation of components of the total switching costs such as system implementation and integration costs, O_{xx}, operational costs, P_{xx} : partnership instability costs and T_{xx}, switching costs for each partner can be developed. Currently, the total switching costs are assumed to be in numbers. In reality, these numbers represent the additional amount a particular partner has to spend in order to update its systems and processes to be compatible for collaboration. However, these costs can be considered as non-integers in the form of “high”, “medium”, or “low”. The collaboration model can be further developed to incorporate expected net benefits such as cycle time reductions, service level gains, inventory and product cost reductions to be realized as a result of going into any of the three types of collaboration. The expected benefits can then be compared with the total switching costs for calculating the net benefits for each of the three types of collaboration. The framework proposed in the study is from retailer and supplier industry’s point of view. Through bibliography research, more partner selection factors such as safety, packaging, aesthetics, maintenance and reliability can be added so as to allow the framework to be applied to problems in a variety of areas and industries.

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Appendix A

Collaboration model

cpp code

```
#include "retailer1.h"
#include <iostream>
#include <string>
#include "conio.h"
#include <fstream>
#include <sstream>
#include <string>
using namespace std;

/*
system::system(){
	num = 0;
}
*/
supplier::supplier(){
	decision = -1;
	static int count = 0;
	count++;
	suppN = count;

	/*
	sxxp = 0;
	oxxp = 0;
	pxxp = 0;
	txxp = 0;

	sxxf=  0;
	oxxf = 0;
	pxxf = 0;
	txxf = 0;
	*/
}

int supplier::decide(){
	int TFC = 0, TPC = 0, TNC = 0;
	int * minimum;
	minimum = new int[rets.size()];

	int * kind;
	kind = new int[rets.size()];

	int *a;
	a = new int[4];

	int *b;
	b = new int[4];
```

```
	int *c;
	c = new int[4];

	int retNumber = -1;
	int finalminimum = -1;
	int kindofcol = -1;
	if (rets.size() != 0)
	{
		for(int i = 0; i < rets.size(); i++){
			TFC = 0;
			TPC = 0;
			TNC = 0;
			a = rets[i].getDataFC();
			b = rets[i].getDataPC();
			c = rets[i].getDataNC();
			for( int j = 0; j < 4; j++){
				TFC += a[j];
				TPC += b[j];
				TNC += c[j];
			}

			//cout << TFC << "    " << TPC << "     "<< TNC << endl;
			if(TFC < TPC && TFC < TNC){
				cout << "Supplier # " << suppN << " should do full
collaboration with retailer # " << i+1 << endl << endl;
				minimum[i] =  TFC;
				kind[i] = 0;
			}
			else if(TPC < TNC && TPC < TFC){
				cout << "Supplier # " << suppN << " should do partial
collaboration with retailer # " << i+1<< endl << endl;
				minimum[i] =  TPC;
				kind[i] = 1;
			}
			else{
				cout << "Supplier # " << suppN << " should do no collaboration
with retailer # " << i+1 << endl << endl;
				minimum[i] =  TNC;
				kind[i] = 2;
			}
		}
		/*
		finalminimum = minimum[0];
		kindofcol = kind[0];
		retNumber = 1;

		for (int m = 0; m < rets.size(); m++){

			cout << "minimum array gives: " << minimum[m] << endl;
			cout << "kind is: " << kind[m]  << endl;
			if(finalminimum > minimum[m]){
					finalminimum = minimum[m];
					kindofcol = kind[m];
					retNumber = m+1;
			}
		}
		*/
```

```
	}

	/*
	if(kindofcol == 0)
		cout << "Supplier # " << suppN << "should do full collaboration with 
retailer # " << retNumber << endl;
	else if(kindofcol == 1)
		cout << "Supplier # " << suppN << "should do partial collaboration with 
retailer # " << retNumber << endl;
	else if(kindofcol == 2)
		cout << "Supplier # " << suppN << "should do no collaboration with retailer 
# " << retNumber << endl;
	else
		cout << "Supplier # " << suppN << "should do neither" << endl;
	*/
	return 0;
}


int retailer::decide(){
	int TFC = 0, TPC = 0, TNC = 0;
	int * minimum;
	minimum = new int[supps.size()];

	int * kind;
	kind = new int[supps.size()];

	int *a;
	a = new int[4];

	int *b;
	b = new int[4];

	int *c;
	c = new int[4];

	int suppNumber = -1;
	int finalminimum = -1;
	int kindofcol = -1;
	if (supps.size() != 0)
	{
		for(int i = 0; i < supps.size(); i++){
			a = supps[i].getDataFC();
			b = supps[i].getDataPC();
			c = supps[i].getDataNC();
			TFC = 0;
			TPC = 0;
			TNC = 0;
			for( int j = 0; j < 4; j++){
				TFC += a[j];
				TPC += b[j];
				TNC += c[j];
			}
			//cout << TFC << "    " << TPC << "     "<< TNC << endl;
			if(TFC < TPC && TFC < TNC){
				cout << "Retailer # " << retN << " should do full 
collaboration with supplier # " << i+1 << endl << endl;
				minimum[i] =  TFC;
```

```
                        kind[i] = 0;
                    }
                    else if(TPC < TNC && TPC < TFC){
                        cout << "Retailer # " << retN << " should do partial
collaboration with supplier # " << i+1 << endl << endl;
                        minimum[i] =  TPC;
                        kind[i] = 1;
                    }
                    else{
                        cout << "Retailer # " << retN << " should do no collaboration
with supplier # " << i+1 << endl << endl;
                        minimum[i] =  TNC;
                        kind[i] = 2;
                    }
            }
            /*
            finalminimum = minimum[0];
            kindofcol = kind[0];
            suppNumber = 1;
            for (int m = 0; m < supps.size(); m++){
                    //cout << "minimum array gives: " << minimum[m] << endl;
                    //cout << "kind is: " << kind[m]  << endl;

                    if(finalminimum > minimum[m]){
                                finalminimum = minimum[m];
                                kindofcol = kind[m];
                                suppNumber = m+1;
                    }
            }
            */
    }
    /*
    if(kindofcol == 0)
            cout << "Retailer # " << retN << "should do full collaboration with
supplier # " << suppNumber << endl;
    else if(kindofcol == 1)
            cout << "Retailer # " << retN << "should do partial collaboration with
supplier # " << suppNumber << endl;
    else if(kindofcol == 2)
            cout << "Retailer # " << retN << "should do no collaboration with supplier
# " << suppNumber << endl;
    else
            cout << "Retailer # " << retN << "should do neither" << endl;
    */
    return 0;
}


retailer::retailer(){
    decision = -1;
    static int count = 0;
    count++;
    retN = count;

}


void retailer::setDataFC(int sf, int of, int pf, int tf){
```

```
	FC = new int[4];

	FC[0] = sf;
	FC[1] = of;
	FC[2] = pf;
	FC[3] = tf;
}
void retailer::setDataPC(int sf, int of, int pf, int tf){
	PC = new int[4];

	PC[0] = sf;
	PC[1] = of;
	PC[2] = pf;
	PC[3] = tf;
}void retailer::setDataNC(int sf, int of, int pf, int tf){
	NC = new int[4];

	NC[0] = sf;
	NC[1] = of;
	NC[2] = pf;
	NC[3] = tf;
}

void supplier::setDataFC(int sf, int of, int pf, int tf){
	FC = new int[4];

	FC[0] = sf;
	FC[1] = of;
	FC[2] = pf;
	FC[3] = tf;
}
void supplier::setDataPC(int sf, int of, int pf, int tf){
	PC = new int[4];

	PC[0] = sf;
	PC[1] = of;
	PC[2] = pf;
	PC[3] = tf;
}void supplier::setDataNC(int sf, int of, int pf, int tf){
	NC = new int[4];

	NC[0] = sf;
	NC[1] = of;
	NC[2] = pf;
	NC[3] = tf;
}

int *supplier::getDataFC(){
	return FC;
}
int *supplier::getDataPC(){
	return PC;
}
int *supplier::getDataNC(){
	return NC;
}

int *retailer::getDataFC(){
```

```
        return FC;
}
int *retailer::getDataPC(){
        return PC;
}
int *retailer::getDataNC(){
        return NC;
}
/*
void supplier::setData(int sf, int of, int pf, int tf,  int sp,int op,int pp ,int tp){
        sxxp = sp;
        oxxp = op;
        pxxp = pp;
        txxp = tp;

        sxxf=  sf;
        oxxf = of;
        pxxf = pf;
        txxf = tf;
}
*/


int main(){

        supplier s1;
        supplier s2;
        supplier s3;
        supplier s4;
        //vector <retailer> ret;
        retailer r1;




ifstream infile("thefile1.txt");
string line;

  vector<int> v;
while (getline(infile, line))
{
  istringstream iss(line);
  int n;


  while (iss >> n)
  {
    v.push_back(n);
  }

  // do something useful with v
}
int c = 0;
for(int i = 0; i < 3;i++){
        if(i==0){
                s1.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
```

```
                s1.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
                s1.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}


        supps.push_back(s1);



for(int i = 0; i < 3;i++){
        if(i==0){
                s2.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
                s2.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
                s2.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}

        supps.push_back(s2);



for(int i = 0; i < 3;i++){
        if(i==0){
                s3.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
                s3.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
                s3.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}

        supps.push_back(s3);

for(int i = 0; i < 3;i++){
        if(i==0){
                s4.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
                s4.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
                s4.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}
```

```
        supps.push_back(s4);

        int a2 = r1.decide();

        while(rets.size()!=0){
          for(int i = 0; i < rets.size(); i++){
              rets.erase(rets.begin() + i);
          }
        }
        while(supps.size()!=0){
          for(int j = 0; j < supps.size(); j++){
              supps.erase(supps.begin() + j);
          }
        }

for(int i = 0; i < 3;i++){
        if(i==0){
               r1.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
               r1.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
               r1.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}


        rets.push_back(r1);

        int a4 = s1.decide();

        while(rets.size()!=0){
          for(int i = 0; i < rets.size(); i++){
              rets.erase(rets.begin() + i);
          }
        }

for(int i = 0; i < 3;i++){
        if(i==0){
               r1.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
        }
        else if(i==1){
               r1.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
        }
        else
               r1.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

        c++;
}

        rets.push_back(r1);

        int a5 = s2.decide();

        while(rets.size()!=0){
          for(int i = 0; i < rets.size(); i++){
```

```
            rets.erase(rets.begin() + i);
        }
      }

      for(int i = 0; i < 3;i++){
      if(i==0){
             r1.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
      }
      else if(i==1){
             r1.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
      }
      else
             r1.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

      c++;
}

      rets.push_back(r1);

      int a6 = s3.decide();

      while(rets.size()!=0){
        for(int i = 0; i < rets.size(); i++){
            rets.erase(rets.begin() + i);
        }
      }
for(int i = 0; i < 3;i++){
      if(i==0){
             s2.setDataFC(v[4*c + 0] ,v[4*c + 1],v[4*c + 2],v[4*c + 3]);
      }
      else if(i==1){
             s2.setDataPC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);
      }
      else
             s2.setDataNC(v[4*c + 0] ,v[(4*c) + 1],v[(4*c) + 2],v[4*c + 3]);

      c++;
}

      rets.push_back(r1);

      int a7 = s4.decide();


      getch();
      return 0;
}
```

Header file

```
#include "string.h"
#include <vector>


class supplier{
private:
	int decision;
	int suppN;
	int * FC;
	int * PC;
	int * NC;
/*
	int sxxp;
	int oxxp;
	int pxxp;
	int txxp;

	int sxxf;
	int oxxf;
	int pxxf;
	int txxf;
*/
public:
	supplier();
	int decide();
	/*
	int getsxxp();
	int getoxxp();
	int getpxxp();
	int gettxxp();

	int getsxxf();
	int getoxxf();
	int getpxxf();
	int gettxxf();
	*/
	int *getDataFC();
	int *getDataPC();
	int *getDataNC();

	void setDataFC(int, int, int, int);
	void setDataPC(int, int, int, int);
	void setDataNC(int, int, int, int);
	friend class retailer;
};

class retailer{
private:
	/*
	int sxxp;
	int oxxp;
	int pxxp;
	int txxp;

	int sxxf;
```

```
	int oxxf;
	int pxxf;
	int txxf;
	*/
	int retN;
	int * FC;
	int * PC;
	int * NC;
	int decision;
public:
	friend class supplier;
	retailer();
	/*
	int getsxxp();
	int getoxxp();
	int getpxxp();
	int gettxxp();

	int getsxxf();
	int getoxxf();
	int getpxxf();
	int gettxxf();
	void setData(int, int, int, int,  int,int,int,int);
	int decide(int,int,int,int,   int,int,int,int );
	*/
	int *getDataFC();
	int *getDataPC();
	int *getDataNC();

	void setDataFC(int, int, int, int);
	void setDataPC(int, int, int, int);
	void setDataNC(int, int, int, int);

	int decide();

};

	std::vector <supplier> supps;
	std::vector <retailer> rets;

	/*
class system{

public:
	friend class supplier;
	friend class retailer;

	system();
	std::vector <supplier> supps;
	std::vector <retailer> rets;

private:
	int num;


};
*/
```