CHAPTER II
LITERATURE REVIEWS

This chapter will show briefly discussion about literature reviews for this research. We separate this chapter into four sections. The first section will discuss on healthcare supply chain, the second will present about criteria and sub-criteria for healthcare performance, the third and last section will describe about Delphi and Analytical Networks Process (ANP) method.

2.1 Healthcare Supply Chain

2.1.1 Challenges to develop an effective healthcare supply chain management

Healthcare supply chain is well known as it is an unique health sector supply chain and it is also classified as professional services type (Silvestro et al., 1992). The healthcare supply chain is vast, complex, essential, and purportedly effective but inefficient (Nachtmann and Pohl, 2009). The Healthcare supply chain consists of many supply chains such as pharmaceutical supply chain, medical appliances supply chain etc. The numerous dedicated individuals interact every day to get the right medical products to the right customer at the right time. There are four macro processes associated with the unique challenge of hospital and hospital system supply chain which needed to consider. These are customer relationship management (CRM), internal supply chain management (ISM), supplier relationship management (SRM), and purchasing partner management (PPM) (Schneller and Smeltzer, 2006). For the unique health sector, it needed the supply chain manager to see himself or herself as having relationships with others organization to close the gap among suppliers, distributors, information intermediaries, and GPO and the hospital according to the structure of healthcare supply chain (Figure 2.1). These partners within the supply chain push heavily efforts for excellence inside and outside of their

organizations among daily challenges including volatile customer demand, low visibility, diverse processes, and a complex payment structure (Nachtmann and Pohl, 2009).

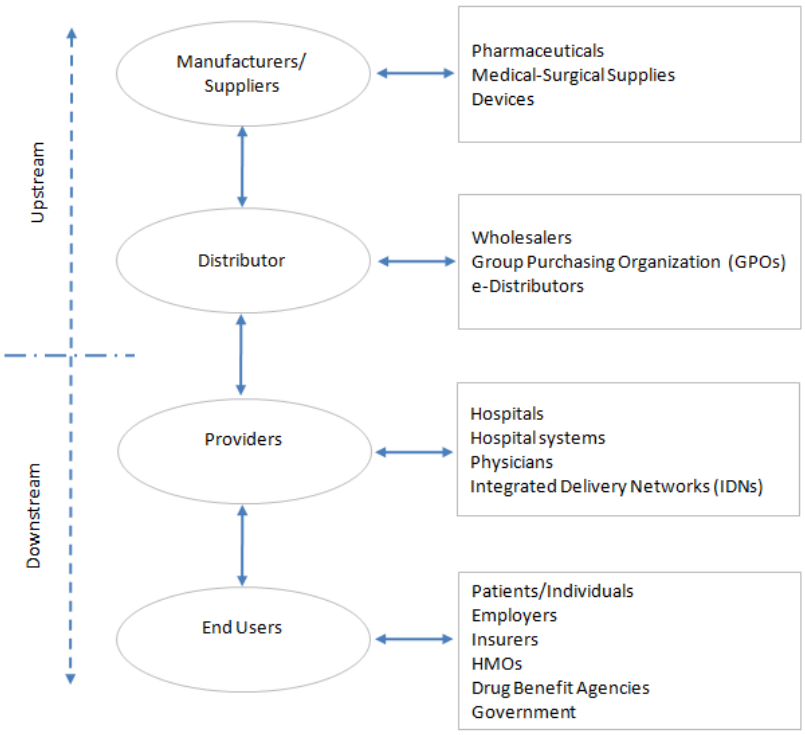

Figure 2.1: The structure of healthcare supply chain

Source: Ozcan, A. Quantitative methods in health care management second edition, 2009

While literature validating the importance of supply chain management is plentiful, there is the limited academic literature that addresses the challenges unique to the healthcare supply chain. However, Burns (2001) identified an excellent description of the challenge inherent in the healthcare industry, including:

- Constantly evolving technology affects to short product life cycles and high cost for physician preference items.
- Difficult in forecasting frequency, duration and primary diagnoses for patient visits and the associated product requirement.
- Lack of the standardized coding of healthcare products and commodities.

- Lack of capital to build a sophisticated information technology infrastructure to support supply chain management efforts.
- Inadequate business education and SCM capability among hospital-based buyers.

Everard (2001) revealed the fact that the lack of progress in SCM that each link with the healthcare supply chain operates solely in its own best interests. However, most healthcare professionals generally agree that changing is necessary, fear of making the first move limits progress. To investigate the environmental issues, the critical players within the healthcare supply chain who are grouped purchasing organizations (GPOs), distributors and hospitals are examined and their role in enabling or inhibiting supply chain efforts. GPOs are the integral part of healthcare supply chain and signing the contract that cover 72 percent of all products purchased by hospitals (Werner, 2002)

2.2 Why Is the Supply Chain Performance Measurement Important?

Performance measurement is a way to improve and to quantify the effectiveness and efficiency of a supply chain that it is the crucial issue for many companies (Neely et al., 1995; Beamon, 1999; Shepherd and Günter, 2006). Effectiveness is the degrees to which objectives are achieved and the extent to which targeted problem are resolved without aimed to cost. Efficiency is an important factor in determination of productivity. Performance measurement systems (PMSs) are the tools that can support to the performance measurement process using by decision makers. Decision makers use PMS that maintains various performance measures for different purposes such as supporting decision making and management control, results evaluation, coordination and communication improvement (Neely et al., 1995; Simons, 2000).

McKone-Sweet et al. (2005) revealed the barriers in implementing of SCM practices through the literature review and case studies within the healthcare industry supply chain that lacked of executive support, misaligned or conflicting incentives, needed for data collection and performance measurement, limited education on supply chain. Inefficiencies in the health care supply chain could be significantly improved

through the application of supply-chain best practices from other industries run (Kumar et al, 2005). Prior to the changes, there was an urgent need to assess the current performance and also develop a suitable performance measurement system for the health care industry. There are different performance metrics of various industries proposed by authors such as Gunasekaran et al., 2004 has proposed performance metrics by classified into each management level including strategic, tactical, and operational level. Kumar et al., 2005 have classified into six different perspectives of Balanced Scorecard Concepts (BSC) for procurement performance measurement system in the health care industry and Bhagwat and Sharma, 2007 study has applied the BSC concept with analytical hierarchy process (AHP) for performance measurement in a supply chain by ranking the importance and selecting appropriate metrics and Chia et al. (2009) proposed the four different perspectives of Balanced Scorecard Concepts (BSC) framework, Wong and Wong (2007) studies has proposed Data Envelopment Analytic (DEA) in measuring internal supply chain performance, Chan (2003) has proposed the framework of performance measurement that consisted of 7 criteria of cost, resource utilization, flexibility, visibility, trust, and innovativeness through using Analytical Hieratical Process (AHP) method for evaluating performance and this study is classified as dimension based measurement system (DBMS) (Ramaa, 2009) while Huang et al. (2004) has combined this technique with SCOR model, and Analytical Network Process (ANP), for example, Agarwal and Shankar (2002) presented the performance framework for evaluating the priorities of performance improvement in a supply chain based on ANP method, etc.

2.3 The Criteria and Sub-criteria for Healthcare Supply Chain Performance

In performance measurement, there are complicate and difficult to measure for healthcare supply chain. Healthcare supply chain should consider both quantitative and qualitative criteria. Therefore, criteria and sub-criteria that involved healthcare supply chain performance are reviewed in this section. Literatures can explore a big picture of performance measurement in supply chains and there is no more difference in category measures. For example, Chan (2003) proposed the framework of

performance measurement in a supply chain and measures were categorized into 7 categories of cost, resource utilization, time, visibility, trust, flexibility and innovativeness. Schönsleben (2004) categorized measures in this study into 4 categories of quality, cost, delivery and flexibility while the study of Shepherd and Günter (2006) has reviewed the literature about performance measurement of supply chain in the past and categorized measures into 5 categories of cost, time, quality, flexibility and innovativeness. Others researchers have different categories according to the literatures review in App.I. Time and quality measures reflect the efficient ability of a supply chain in delivering a high customers services, while flexibility and innovativeness reflect the ability to response when demand or supply changed. In the agility literature, flexibility and innovativeness are important strategic drivers for a supply chain development in the future (Lee, 2004; Morgan, 2004).

App.A presents the evaluating criteria and approaches of authors that shows how the important of criteria and different focused measures of each author in the past. For the overall proportion of the measures from literature reviews, they are 33.18 percent of quality, 21.80 percent of cost, 20.38 percent of time, 18 percent of flexibility, 3.80 percent of innovativeness and 2.84 percent of collaboration as following Figure 2.2. For the brief of criteria and sub-criteria definitions, it shows in Table 2.1. Table 2.2, it implied that there are few researchers who pay attention on collaboration in a supply chain. From the literatures reviewed, there is no research that included collaboration criterion with others in performance measurement.

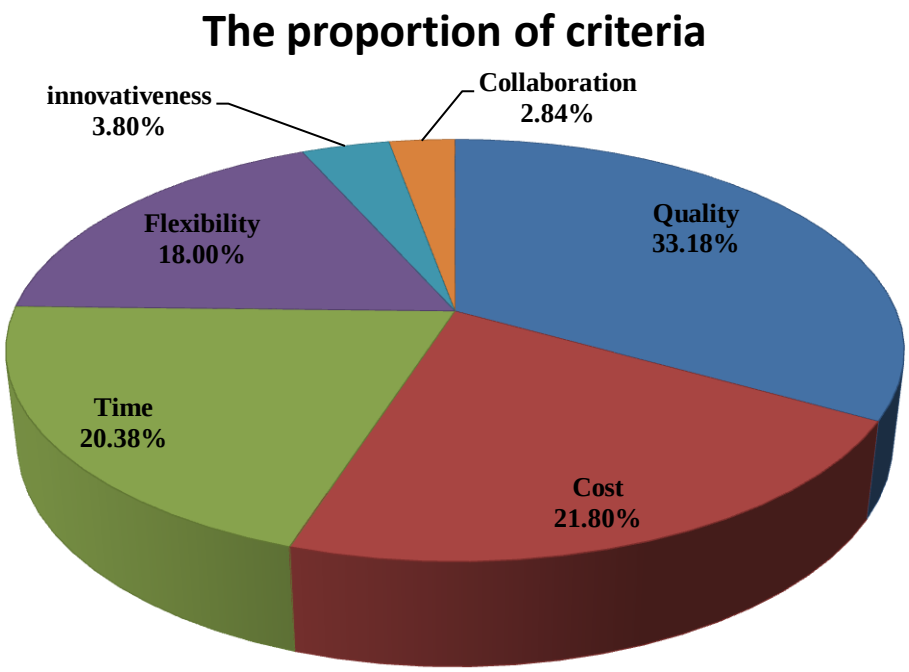

Figure 2.2: The proportion of criteria from literatures review

Source: Appendix A

2.3.1 Quality

There is a lot of works that utilized the quality criterion as a performance measure in a supply chains (Beamon, 1999). Quality means the standard of product and services provided that outcomes resulting related to customer satisfaction (Chan, 2003).

2.2.1.1 Backorders

The situation that requested products are out of stock, so products backordered is due to stock-out as stock-out probability measure (Chan, 2003). Average backorders can be measured by the number of products backordered divided by the number of products. For this study, it means the number of medicines and medical appliances that cannot send to customers (providers such as hospitals) according customer requested in that time and need for delivering the orders to customers (providers such as hospitals) later.

2.2.1.2 Delivery accuracy

It can be measured the percentage of inaccurate delivery of product delivered to customer (Chan, 2003) such as the quantity of product ordered can be delivered to customer accuracy according to purchase order (PO). For this study, it means the accuracy of medicines and medical appliances delivering to customer (providers such as hospitals).

2.2.1.3 Fill rate

The majority of GPOs, distributors and healthcare providers, these are interested to improve their service levels and fill rates (Nachtmann and Pohl, 2009). Frequent fulfills a stock; it means that it will be increased costs such as worker who involved costs, etc. It can be measured by the proportion of customer's orders that providers can fulfill (Beamon, 1999; Chan, 2003; Chan and Qi, 2003). The degree of fulfillment can effect to the effectiveness of the procurement process in the supply chain (Kumar et al., 2005). For this study, it means the number of medicines and medical appliances that can fill the customer (providers such as hospitals)'s order.

2.2.1.4 Delivery reliability

It can be measured by the number of timeliness and error free per order that customers can meet (Chan and Qi, 2003). For this study, it means the delivery that met the timeliness and error free per customer customers (providers such as hospitals) ordering.

2.2.1.5 Distribution planning

It is the important measure that can represent how about the potential of organization performance to distribute products to their customers. The efficiency of distribution planning that can be measured by the percent of successful products distributed to customers (Gunasekaran et al., 2001). For this study, it means that the efficient of distribution planning for specified customers.

2.2.1.6 Delivery invoice method

The efficiency of time and accuracy that can be meet while delivery invoice to customers such as using SAP method in making and delivery an invoice to customer (Gunasekaran et al., 2001). The majority of GPOs, distributors and healthcare providers, these are interested to improve their invoice accuracy or invoice method (Nachtmann and Pohl, 2009). For this study, it means that used the

delivery invoice method to reduce mistakes and waste time for improving performance.

2.2.1.7 Driver reliability

The measurement is by directly driver performance while delivery products (Gunasekaran et al., 2001) such as driver's experiences in driving or the number of individual accidents occurred from driving. For this study, it means the reliability of truck driver while delivery of medicines and medical appliances to customers (providers such as hospitals).

2.2.1.8 Accuracy of forecasting techniques

The accuracy of forecasting technique is so important for forecasting demand as inventory management. If there is high stock level, it means that costs involved inventory costs occurred. Thus, the stock level should be as less as possible. The measurement is by directly matching the demand forecasting with actual demand (Gunasekaran et al., 2001). For this study, it means the accurate planning of medicines and medical appliances requirement in forecasting to meet actual demand.

2.2.1.9 Customer dissatisfaction

Shepherd & Günter (2006) addressed that the customer satisfaction measure Christopher (1994) is so important measure for the future research. It is the direct measurement of quality criterion. It can be measured the customer satisfaction level directly by the number of customer complaints (Beamon, 1999; Chan, 2003). For this study, it means the satisfaction of customers (providers such as hospitals) perceived.

2.3.2 Cost

There are complex attributes of total costs for each industry and the contribution of each attribute may be different. For electronic industry, each electronic part is cheap and it is the fast-moving industry. Electronic parts should be kept only in sufficient quantity as any excess parts are not useful while manufacturing, inventory and warehouse cost should be less as part cost. Many enterprises perceived that its profit is directly affected by the total cost of its operations, so cost measurement is so important and influence to the whole its performance. McDermott

and Stock (2007) study, addressed that healthcare costs have become more important issue and common measures in many researches.

2.2.2.1 Overhead cost

It is total current landed costs (Chan, 2003).

For this study, it means the costs that associated with accounting fees, advertising, depreciation, insurance, interest, legal fees, rent, repairs, supplies, taxes, telephone bills, travel and utilities costs.

2.2.2.2 Warehouse cost

It is a cost that associated with allocation from one tier to another and usually involves the finished goods or products (Chan, 2003; Chan and Qi, 2003). For this study, it means the costs that used for allocating the medicines and medical appliances in warehouse.

2.2.2.3 Distribution cost

This includes the transportation, handling, and duty cost (Beamon, 1999; Chan, 2003). For this study, it means the costs that incurred by distributors in moving the medicines and medical appliances from distributors to provider (such as hospitals) including transportation, handling, and duty cost.

2.2.2.4 Return on investment

The amount of gain from investment minus cost of investment, then divided by cost of investment (Beamon, 1999). For this study, it means the costs that planed for gaining from investment such as investment for implementing SAP.

2.2.2.5 Transport productivity

It is costs that associated with investment for increasing transport productivity such as having own trucks, contracting with transport outsources for benefits of urgent transport requirements (Chan, 2003). For this study, it means that considered the ability in transporting the medicines and medical appliances to customers (providers such as hospital).

2.2.2.6 Transaction cost

It is costs that occurred between suppliers and customers such as invoice faxing costs, product insurance costs, employee's costs for preparing documents, etc (Schneller and Smeltzer, 2006). For this study, it means the cost that occurred between distributors (such as group purchasing organization) and customers

(providers such as hospitals) such as faxing cost, product insurance cost, employee's costs for preparing documents etc.

2.2.2.7 Administrative cost

It is costs that associated organizational administration such as total ownership costs analysis etc (Schneller and Smeltzer, 2006). For this study, it means that considered to the cost for administrating related to the organization as a whole such as salaries of senior executives and costs of general services (such as accounting and contracting).

2.2.2.8 Economic order quantity

It is the decreased costs that affected from using economic order quantity method (Gunasekaran et al., 2001). For this study, it means the cost of the medicines and medical appliances that can be reduced from using economic order quantity method.

2.2.2.9 Inventory investment

It is costs that associated with inventory investment such as having own warehouse (Beamon, 1999). For this study, it means the costs that considered for investment in the medicines and medical appliances inventory.

2.3.3 Time

There is much published research on time as a performance measure in a supply chain (Chan, 2003; Beamon, 1999; Gunasekaran et al., 2001; Agarwarl, 2003; 2006). Time is well-known that time is money for anywhere in the world. If a company can be supplied raw materials faster than competitors, customers would pay trusts and remains their relationship with that company.

2.2.3.1 Customer response time

Sometime, it also called order cycle time (Gunasekaran et al., 2004). It refers to the time that is between the receiving of customer's order and delivering of finished goods to customer (Kuglin 1998; Beamon, 1999; Chan, 2003). It is an important measure as competitive advantage and the reduction of order cycle time can reach to reduce the supply chain response time (Christopher, 1992). It can measure cycle time that consists of the reaction time, manufacturing time, and

transportation time (Beamon, 1999; Chan, 2003). For this study, it means the time that responded to the ordering of the medicines and medical appliances each cycle time.

2.2.3.2 Delivery Lead time

It can measure the time required at the beginning of product producing until the time that it is completely processed (Gunasekaran et al., 2001; Chan, 2003). Lead time is made up of queuing time, processing time, batching time, handling time, and transportation time (Yucesan & Xaview, 2000). For this study, it means that considered to the lead time of delivering the medicines and medical appliances ordering to customers (providers such as hospitals) each time.

2.2.3.3 On-time delivery

The percent of orders delivered to customer on or before due date. There are similar measures in Beamon (1999) study that measured in product lateness, average lateness of orders, and average earliness of orders. For this study, it means that the ability of medicines and medical appliances delivery that can deliver to customers (providers such as hospitals) within due date.

2.3.4 Flexibility

In a flexible supply chain, there are many advantages Beamon (1999) such as reduction in number of backorder, increased customer satisfaction, ability to respond to demand variations, etc. There are two categories of flexibility Slack (1983) that are: range flexibility and response flexibility. Range flexibility means the extent of the operation that can be changed. Response flexibility refers to the cost or time or both of the operations which can be changed. However, there are a limit and not cover all of the overall flexibility types. For this research, there are various important sub-criteria on flexibility criteria.

2.2.4.1 Volume flexibility

The percent of volume changing performance that can accommodate without incurring high costs (Beamon, 1999; Chan, 2003). For this study, it means that the volume of medicines and medical appliances ordering that can changeable volumes to meet the specified requirements.

2.2.4.2 Order flexibility

The percent of order changing performance that can accommodate without incurring high costs (Chan and Qi, 2003). For this study, it means that the appropriate flexibility of medicines and medical appliances ordering that can accommodate to meet the same requirements.

2.2.4.3 Transport flexibility

The percent of transportation changing performance that can accommodate without incurring high costs or the percent of slack time can be reduces (Chan, 2003). For this study, it means that the appropriate flexibility of medicines and medical appliances transportation that can accommodate to meet specified requirements.

2.2.4.4 Resource flexibility

Resource flexibility is similar to managing the resources to be more efficiency as possible. The medical knowledge kills and experiences of service providers (nurses, specialists, and general practitioners) are the most important factors for responding to various needs of patients (Bowen and Youngdahl, 1998; Rahimnia and Moghadasian, 2010). The percent of resources changing performance that can accommodate without incurring high costs. For this study, it means that the ability of planning to optimize the resources at various working areas such as workforces.

2.2.4.5 Responsiveness to urgent deliveries

The percent of responsiveness to urgent customer's order performance that can accommodate without incurring high costs (Gunasekaran et al., 2001; Chan, 2003). For this study, it means that the ability to respond with the need of urgent deliveries.

2.2.4.6 Flexibility of service system

The flexibility of service system that meet particular customer needs The percent of servicing performance that can accommodate without incurring high costs and meet individual customer needs (Gunasekaran et al., 2001). For this study, it means that the ability to provide appropriate services to customers (providers such as hospitals).

2.3.5 Innovativeness

Nowadays, the competition among industries is strong, so having particular product to gain competitive advantage over competitor is so important. When an innovative product or service have introduced in any level of manufacturers or distributors, it would make the whole supply chain to be more specialize. According to Shepherd and Günter (2006) study, it has suggested that the future research should be addressed the qualitative metrics and non-financial measures of innovativeness.

2.2.5.1 New technology

It can be measured by the percentage of increased in efficiency or decreased in time after implementing new technology within a period (Chan, 2003). For this study, it means that used of new technology to maximize the potential of planning process.

2.2.5.2 New product launched

It can be measured by the sales of new product launched compare with the whole sales within a period of time as percentage (Chan, 2003). For this study, it means that considered the value-added of products or services to meet specified requirements.

2.3.6 Collaboration

There is a concept issued that have not been discussed in details in previous work, it is a collaboration measure. Collaboration is playing the important role for every supply chain in nowadays (Simatupang and Sridharan, 2004a). Shepherd and Günter, 2006 presents his research that the future direction of research should be developed measures of supply chain relationships and the SC as a whole and it should be emphasized on measures of inter-organizational performance rather than intra-organizational performance. The way to achieve the significant global performance improvements, organizations should be restructured their relationships with their both upstream and downstream company along the whole supply chain (Sculli et al., 2001). For healthcare sector, the collaboration between different hospitals is necessary (Rahimnia and Moghadasian, 2010). The majority of Manufacturers, GPOs, distributors and healthcare providers, these are interested to establish strategic partnerships and alliances (Nachtmann and Pohl, 2009). The environment of supply

chain, there is the issues of the collaboration between supply chain partners which utilized in building strong relationship with each other (Cai et al., 2010).

2.2.6.1 Information sharing

It is the first point of supply chain collaboration. The aims of information sharing are to capture and to publicize timely and involved information that will be help decision makers to plan and supply chain operations can be more control (Simatupang and Sridharan, 2004b). There are various processes of shared data such as point of sale (POS), demand forecasts, inventory levels, delivery schedules, and inventory costs (Lee and Whang, 2000). The sharing data is about required demand, remained supplies, and common performance. Many studies have discovered that information sharing enables the chain member to be better performance Lee et al. (1997) and Whipple et al. (2002) and can increase the efficiency of supply chain operations, especially the complex supply chain (Shafieezadeh and Hajfataliha, 2009). The implementing of a PMS, the collaboration and information sharing of the supply chain are the key enabling factor of business-process management (Cai et al., 2010). Previous researches find that information sharing (Simatupang and Sridharan (2005); Vereecke and Muylle (2006)) contribute to performance improvement. For this study, it means that the ability of sharing important information at various points of needs to achieve better performance.

2.2.6.2 Decision synchronization

At the planning and operational context, there is joint decision making occurred as decision synchronization (Simatupang and Sridharan, 2004b). The planning context is about long-term planning such as deciding target markets, product assortments, promotion, and forecasting. The operational context is about ordering and delivery method such as shipping and replenishment schedule. The chain members can perceive the value of all decisions work through decision synchronization aligned common goal of serving end customers. The decision synchronization can increase the fulfillment performance in a supply chain Ramdas and Spekman (2000) and improve on-time delivery and product availability performance (Bowersox et al., 2000). Previous researches (McEvily and Marcus (2005); Simatupang and Sridharan (2005)) find that the decision synchronization contribute to performance improvement. For this study, it means the collaboration to joint decision making related to planning.

2.2.6.3 Incentive alignment

It means the common goals of chain members that they have ordered to share cost, risks, and benefits (Simatupang and Sridharan, 2004b). It also means sharing risks among chain members when demand uncertainty, supply uncertainty or price uncertainty (Fisher, 1997). Rewarding appropriates incentives to chain members that will motivate the chain members to align with supply chain (Simatupang and Sridharan, 2002). In addition, there are several financial and non-financial incentives to employ professionals within the public sector as inequality (Tangchroensathien et al., 2005). Previous researches (Narus and Anderson (1996); McEvily and Marcus (2005); Simatupang and Sridharan (2005)) find that incentive alignment contribute to performance improvement. For this study, it means the appropriate of incentive that rewarded to motivate workforces related to planning process to be aligned with supply chain.

2.2.6.4 Buyer-Supplier relations

It means the relationships between buyer and supplier as history background. It might be measure by the buyer-supplier's credit level (Gunasekaran, 2001). For this study, it means the relationship between providers such as hospital and distributors such as group purchasing organizations (GPOs).

2.2.6.5 Supplier ability to respond to quality problem

Sometimes, customers must face with the situation that the defected product or mistake with product during delivery from supplier has delivered to them, thus they requires who take responsibility for this problems as soon as possible. It can be measure by the number of time that supplier can solve problems (Gunasekaran et al., 2001). For this study, it means the ability of distributors that can respond to quality problem.

Table 2.1 Criteria and sub-criteria definitions

Criteria	Sub-Criteria	Definitions
Quality		
	Backorders	The number of products backordered compared with target of products backordered.
	Delivery accuracy	The percentage of inaccurate delivery of product delivered to customer.
	Fill rate	The proportion of customer's orders that providers can fulfill
	Delivery reliability	The number of timeliness and error free per order that customers can meet
	Distribution planning	The percent of successful products distributed to customers.
	Delivery invoice method	The percent of inaccuracy delivery invoice to customers.
	Driver reliability	The number of accidents occurred during delivering products to customers.
	Accuracy of forecasting techniques	The number of demand forecasting with the number of actual demand.
	Customer dissatisfaction	The number of customer complaints registered.
Cost		
	Overhead cost	A cost that associated with order processing including inventory allocation, scheduling, reporting and shipment documentation as a percentage of sales revenue.
	Warehouse cost	A cost that associated with allocation from one tier to another and usually involves the finished goods or products.
	Distribution cost	A cost that includes the transportation and handling costs, safety stock cost, and duty.
	Return on investment	The amount of gain from investment minus cost of

		investment, then divided by cost of investment.
	Transport productivity	A cost that associated with investment for increasing transport productivity such as having own trucks, contracting with transport outsources for benefits of urgent transport requirements.
	Transaction cost	A cost that occurred between suppliers and customers such as invoice faxing costs, product insurance costs, employees costs for preparing documents, etc.
	Administrative cost	A cost that associated organizational administration such as total ownership costs analysis etc.
	Economic order quantity	The percentage of the decreased costs that affected from using economic order quantity method.
	Inventory investment cost	A cost that associated with inventory investment such as having own warehouse.
Time		
	Customer response time	The number of time between an order and product delivered to customer.
	Lead time	The time required at the beginning of product producing until the time that it is completely processed (e.g. queuing time, processing time, batching time, handling time, and transportation time).
	On-time delivery	The percent of orders delivered to customer on or before due date.
Flexibility		
	Volume flexibility	The percent of volume changing performance that can accommodate without incurring high costs.
	Order flexibility	The percent of order changing performance that can accommodate without incurring high costs.
	Transport flexibility	The percent of transportation changing performance that can accommodate without incurring high costs or the percent of slack time

		can be reduces.
	Resource flexibility	The number of tasks that employees can be performed without incurring high costs compared with target of the number of tasks.
	Responsiveness to urgent deliveries	The percent of responsiveness to urgent customer's order performance that can accommodate without incurring high costs.
	Flexibility of service system	The percent of servicing performance that can accommodate without incurring high costs and meet individual customer needs.
Innovativeness		
	New technology	The percentage of increased in efficiency or decreased in time after implementing new technology within a period.
	New product launched	The sales of new product launched compare with the whole sales within a period of time as percentage
Collaboration		
	Information sharing	The percentage of shared data both tra -and inter-organization.
	Decision synchronization	Decision synchronization can be measured by the percentage of decision synchronization both tra -and inter-organization
	Incentive alignment	The percentage of appropriated incentives to the chain members.
	Buyer-Supplier relations	The buyer-supplier's credit level.
	Supplier ability to respond to quality problem	The percentage of time that supplier can solve problems.

There are the complexity of supply chains and the limitations of measurement systems designed to evaluate the performance of supply chains issues on literatures as reviews of Shepherd and Günter (2006) following:

- Lack of connection with strategy (Beamon, 1999; Chan and Qi, 2003; Gunasekaran et al., 2004);
- Focus on cost to the detriment of non-cost indicators (Beamon, 1999; De Toni and Tonchia, 2001);
- Lack of a balanced approach (Beamon, 1999; Chan, 2003);
- Insufficient focus on customers and competitors (Beamon, 1999);
- Loss of supply chain context, thus encouraging local optimization (Beamon, 1999); and
- Lack of system thinking (Chan, 2003; Chan and Qi, 2003).

This research is attempted to respond these limitations by designing systemic and balanced performance measurement systems. Thus, a classifications of measures of a supply chain performance is addressed in Table 2.2, it can reflect measures according to supply chain processes as SCOR model. Supply chain operations reference or SCOR model was developed by the Supply Chain Council in 1997. It has been described as a "systematic approach for identifying, evaluating and monitoring supply chain performance" (Stephen, 2001). SCOR model provided five groups of metrics at level 1; reliability, responsiveness, flexibility, cost and efficiency. This model has one of the main limitations that it does not offer a systematic method for prioritizing measures (Shepherd, 2006). However, many researchers have to combine it with decision-making tools such as AHP (Chan, 2003; Huang et al., 2004), but there are some disagreement that it is the most appropriate tool. Yang et al. (2009) has proposed the AHP/ANP-based framework for evaluating manufacturing performance and the proposed model can easily identifying which areas require improvement. The comprehensive studies described both qualitative and quantitative performance metrics for SCM and presented by Beamon (1999), Chan (2003), Gunasekaran et al. (2004) and Simatupang and Sridharan (2002). Based on those recent researches, a summary of the performance measures suitable to be used for SCM is presented in Table 2.2. Table 2.2 has delineated measures according to the processes identified in the SCOR model: plan, source, make, deliver or return (customer satisfaction); and whether they measure quality, cost, time, flexibility, innovativeness, or collaboration. In the past, Shepherd and Günter (2006) has presents a taxonomy of measures of supply chain performance as above. These classified issues

are utilized to build the proposed initial ANP-based framework for healthcare supply chain performance measurement whether they measure quality, cost, time, flexibility, innovativeness, or collaboration as Figure 2.3.

Table 2.2 The classifications of measures of supply chain performance

Stages in supply chain	Measure (Sub-criteria)	Criteria						Authors						
		Quality	Cost	Time	Flexibility	Innovativeness	Collaboration	Beamon, 1999	Gunasekaran et al., 2001	Chan, 2003	Chan & Qi, 2003	Simatupang & Sridharan, 2004	Schneller & Smeltzer, 2006	Rahimnia & Moghadsian, 2010
Plan	Fill rate	✓						•		•	•			
	Accuracy of forecasting techniques	✓							•					
	Overhead cost		✓							•				
	Return on Investment		✓					•						
	Customer response time			✓				•	•	•				
	Order flexibility				✓						•			
	New technology					✓				•				
	New product launched					✓				•				
	Decision synchronization						✓					•		
	Incentive alignment						✓					•		
	Transaction cost		✓										•	
	Administrative cost		✓										•	
	Resource flexibility				✓									•
Source	Information sharing						✓					•		
	Buyer-Supplier relations						✓		•					
	Supplier ability to respond to quality problem						✓		•					
Make	Backorders	✓								•				
	Warehouse cost		✓							•	•			
	Inventory investment		✓					•						
	Volume flexibility				✓			•		•				
	Economic order quantity		✓						•					
Deliver	Delivery accuracy	✓								•				
	Delivery reliability	✓									•			
	Distribution planning	✓							•					
	Delivery invoice method	✓							•					
	Driver reliability	✓							•					
	Distribution cost		✓					•		•				
	Transport productivity		✓							•				
	Deliver lead time			✓					•	•				
	On-time delivery			✓				•						
	Transport flexibility				✓					•				
	Responsiveness to urgent deliveries				✓				•	•				
Return	Customer dissatisfaction	✓						•		•				
	Flexibility of service system				✓				•					

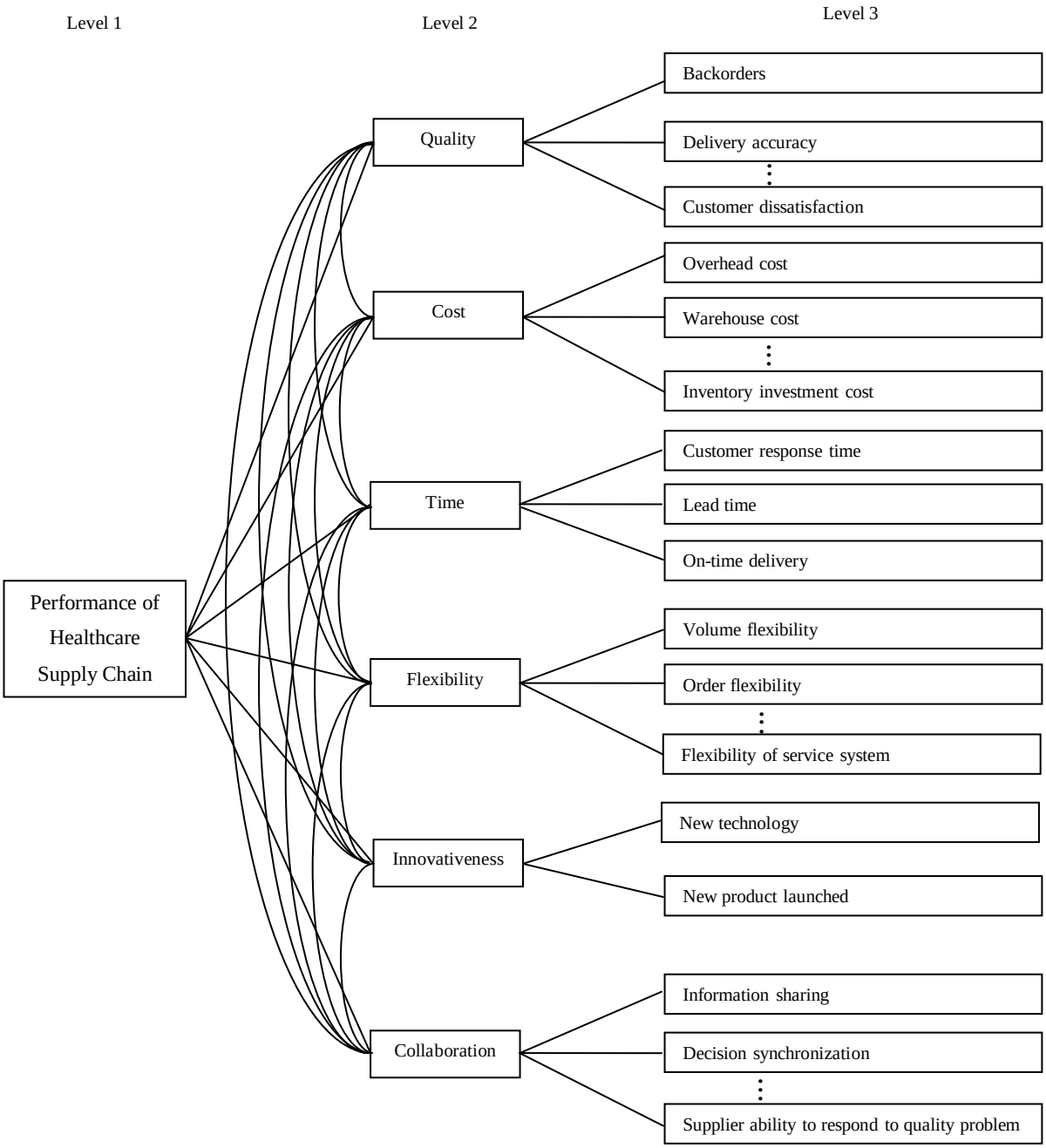

Figure 2.3 The proposed initial ANP-based framework for Healthcare supply chain performance measurement

2.4 Delphi Method

For the purpose of this study, a suitable gathering information method had to be found to get a synthesis of expert opinions while limiting biases. The Delphi method is a suitable method with a more standardized questioning approach.

The Delphi method was named by Olaf Helmer and Norman Dalkey and conducting on behalf of the RAND Corporation in the 1950s as a tool for forecasting scientific and technological developments. The objective was to develop an effective technique to gain the most reliable consensus of among experts (Dalkey and Helmer, 1963). The Delphi method is a valuable research tool that researchers can utilize at various points in their study (Elmer et al., 2010). In the present, The Delphi method has popular and it is interesting among the area of businesses, politic, military, and public health Ponsanong (1997). The adaptation of Delphi process has been commonly used in healthcare research as a method of obtaining agreement among a group of experts (Jones and Hunter, 1995). Table 2.3 shows that health care field is the most second rank of the total study in the past. The Delphi method has five main characteristics: (Loo, 2002; Elmer et al., 2010; Geist, 2010)

- Participants consist of a panel of carefully selected experts.
- There is anonymity among experts or individual answers.
- Iteration is required for this method as at least two rounds.
- Structured questionnaires are necessary to obtain qualitative feedback as a controlled feedback.
- Quantitative feedback will be represented to all panelists as statistical group response.

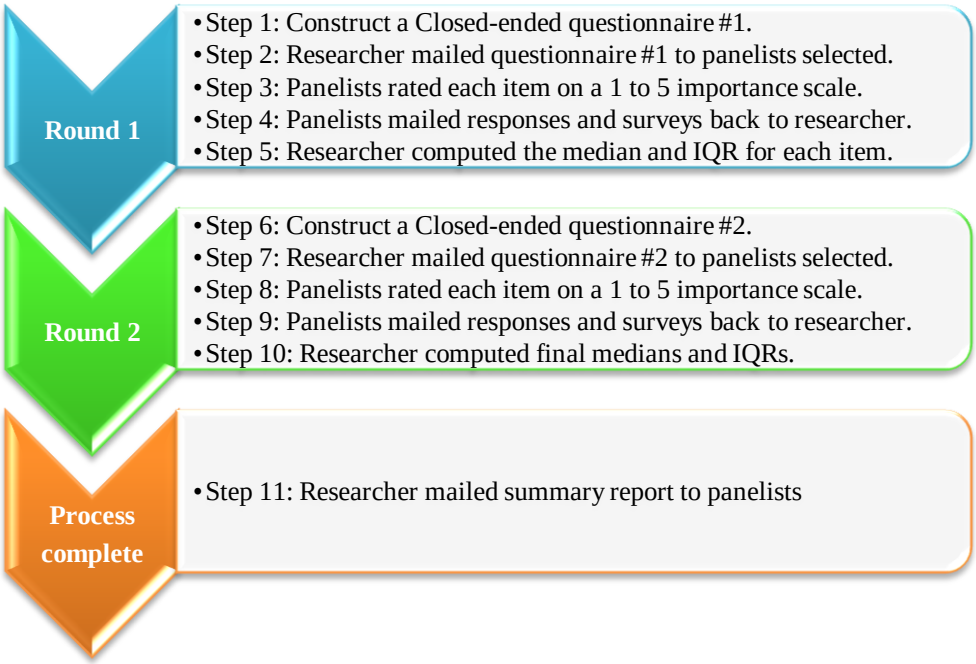

Figure 2.4 Steps of the Modified Delphi study (IQR = interquartile range).

Table 2.3 The classification of primary application papers

Classification	Count
Education	54
Business	12
Management	12
Marketing	12
Manufacturing	7
Finance	6
Economics	3
Human Resources	3
Health Care	27
Information and Technology	9
Real Estate	7
International	5
Social Science	5
Engineering	4
Leisure and Tourism	4
Environment	3
Transportation	3
Miscellaneous	12

Gupta and Clarke, 1996.

The first questionnaire is designed by two ways that are review the literature and then, offering the open-ended questionnaire to the panel of selected expert (Murry and Hammons, 1995a; Jones et al., 2000; Franklin and Hart, 2007). The Delphi method will be utilized for standardized questioning approach in this study. At the conceptualization phase, there are many criteria that should be considered to be an initial framework for the performance measurement of healthcare supply chain and others phase also. Each phase required specific experts who have more knowledge and experiences enough in that field. A group of panelists can help this study to be more effective, reliable, unbiased facts and reduce conflict in face-to-face interaction among panelists. Delphi has widely used in , technology, education, healthcare and others field (Keeney et al., 2001; Loo, 2002; De Villiers et al., 2005).

2.4.1 Impact factors to the Delphi method using as negative

The impact factors are following:

1. The questionnaire that was designed, it has influenced to the decision making of who respondents (experts).

2. Experts may be given unqualified answer because there is no meeting for consulting with others.

3. There might have unexpected problems such as expert cannot understand the aims of study well.

4. There is unmotivated and unwilling experts, so expert must be selected through using purposive sampling, it can help to keep only willing experts (Murry and Hammons, 1995a).

2.4.2 Impact factors to the Delphi method using as positive

The impact factors are following:

1. Time is an important factor. It should be about two months for Delphi processes.

2. Researcher should be selected an expert who is truly involved in area of research.

3. The collaboration of each expert is so important.

4. The total number of participants should be should be 17 participants or more, and then the deviation of answers will be reduced as following Figure 2.4 (Macmillan, 1971).

5. Questionnaire must be designed clearly and ease to understanding.

6. Collected answers of researcher should do as fair summary.

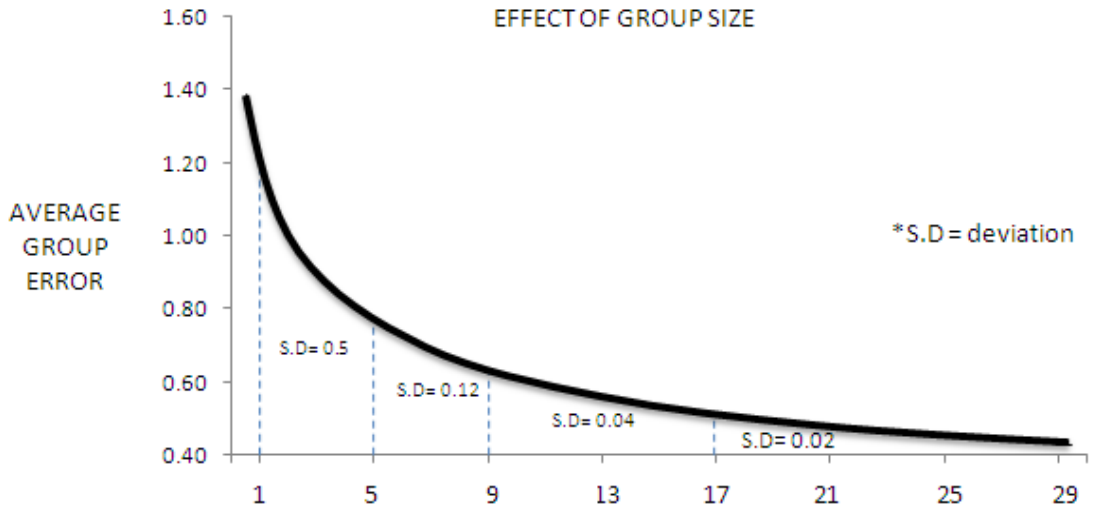

Figure 2.5 The number of expert with the deviation of answers

Source: Macmillan, 1971

2.4.3 Strong and Weakness of Delphi method

Delphi technique has strong and weakness points. For strong point following:

1. Delphi is a technique that is aim to obtain the consensus of opinions among experts and no need any meeting. Data gather has more reliable because Delphi needs panel of selected experts and there is iterative process.

2. Experts can give their opinions freedomly or not affect by another one.

3. Researcher can brainstorm the unlimited opinions from experts.

4. Delphi processes are not complex.

5. The result can lead the researcher be know about prioritizing issues and receive a reasonable consensus.

Delphi technique has strong and weakness points. For weakness point following:

6. Selected experts may not be the really expert in that field, so it can be lead to unreliable consensus.

7. Experts are not willing to cooperate in researching as expected.

8. The analysis of results in each round that the researcher has lacked of prudence and bias.

9. Questionnaires have lost during the sending process to an expert or returned questionnaire of each round is not complete.

2.4.4 Modified Delphi method

Modified Delphi technique is originated from the Delphi technique that it is inefficient processes and not obtain more reliable consensus (Custer et al., 1999). Questionnaire was designed by modifying the methods and processes to be more suitable for objectives of the research. The questionnaire will be designed as close-ended questions that aimed to eliminate the limitations of the open-ended questions used of original Delphi method as Table 2.4. The Modified Delphi method has used in various objectives studied such as exploring method research, future forecasting research, etc. The popular method of questionnaire designed for the first round is closed-ended questions and using Likert scale as instrument. For example, Hartman (1981) has studied the research about the future of students' education in New Jersey, USA with two rounds of questionnaires and utilized the Modified Delphi technique with closed-ended question and 3 levels of Likert scale in the first round. The result of this research explores that the opinions can meet more reliable consensus and reduce the conflict among panelists. Flanders (1989) has studied the research of "Determining curriculum content for nursing/landscape course work in vocational agriculture for the 21st century: a futures study utilizing the Delphi techniques", it has aimed that the uses of the Modified Delphi technique to 25 experts, a Likert scale and total of two rounds for questionnaire designed. It presents the consensus among panelists at 60% level. Murry and Hammons (1995b) has utilized the closed-ended question of the modified Delphi technique with 4 levels of Likert scale and reached the consensus among panelists at 70% level. There are many studies involved the modified Delphi technique. It can show that this technique obtained high consensus among experts and it has the consensus level higher than the original method of Delphi technique

(Taweebooth, 1997). The Delphi rounds can be minimized that researcher should be provided panelists as much information about the research question as possible (Clay-William and Braithwaite, 2009). The study of Clay-Williams and Braithwaite (2009) showed that used a two-round modified Delphi panel in this study and recommended three to four rounds may not be necessary to obtain consensus.

Table 2.4 The comparison between open-ended and close-ended questionnaires

Characteristics	**Open-ended questionnaire**	**Close-ended questionnaire**
1. Questionnaire designing	Easy	Depends on expertise of researcher
2. Questionnaire answering	Freedom answering	Non-freedom answering
3. Time	Long time	Short time
4. Quality of data	More deeps of data collected	Less deeps of data collected
5. Data analysis	Difficulty for data analysis	Easy for data analysis & gathering answers that are relevant objectives
6. Cooperation level	Low cooperation	High cooperation

Taweebooth, 1997.

There are many applications of Delphi method in performance measurement. For example, Chen et al. (2009) has used the Delphi method to identify the performance measure indicators (PMIs) for universities in evaluating the education quality, Bigliardi and Bottani (2010) identified the suitable KPIs in building a BSC model for performance measurement in the food supply chain by Delphi method. The Modified Delphi method, for example, RAND corporation used the modified Delphi method to establish indicators for the care of cancer patients (Porter & Skibber, 2000). In 2005, Gagliardi et al. developed indicators of quality ovarian cancer surgery based on a modified Delphi approach (Gagliardi et al., 2005). Researcher adopted the

modified Delphi technique with the aim of obtaining a high degree of consensus among experts on the measures to be included in this research model.

2.5 Analytical Networks Process (ANP)

2.5.1 Restriction of AHP

Analytic hierarchy process (AHP) is the most commonly model used and it is one of the numerous MADM models which was developed by Saaty (1980). However, there are many limitations issues when applied AHP to the studies. According to Shee et al. (2003) "most of these traditional MADM methods are based on the additive concept along with the independence assumption, but each individual criterion is not always completely independent". Sakis and Talluri (2002) have presented the limitations of AHP as following:

- In the hierarchy, each element is supposed as independence and derived a ratio scale priorities from pair-wise comparisons of various elements at each level. However, the independence among criteria and alternatives is in some case studies.
- The unidirectional interrelationship among decision levels that there is not influence of lower levels on the upper levels. But there is possible elements of the two levels that they will be influence each other (feedback).

Thus, the ANP has been introduced to solve these decision problems.

2.5.2 Introduction to Analytical Network Process (ANP) and applications

ANP, a multi-purpose decision method, was developed by Saaty in 1996 and it originated from AHP (Saaty, 1996). It utilizes for the consideration of complex decision-making problems, inner feedbacks and interdependent relationships. Figure 2.5 presents the structure difference between a hierarchy and a network: (a) a hierarchy; (b) a network. In currently, ANP is widely applied in different decision-making processes such as supplier selection (Sarkis and Talluri, 2002; Bayazit, 2006), Logistics service providers selection (Jharkharia and Shankar, 2007), and strategic for supply chain management, Agarwal and Shankar (2002) used ANP in analyzing

alternatives for improvement in supply chain performance. Similarly, ANP was applied in improving the prioritization of contractor selection criteria study by Li and Cheng (2004). The exploration of the relationship among lead-time, cost, quality, and service level and the leaness and agility of a case of supply chain are modeled using ANP approach by Agarwal (Agarwal et al., 2006). Liao and Chang (2009) applied the ANP in measuring the hospitals performance. In recent year, Carlucci (2010) proposed the ANP-based model for selecting and prioritizing performance indicators while Yüksel and Dağdeviren (2010) applied ANP with Balanced Scorecard.

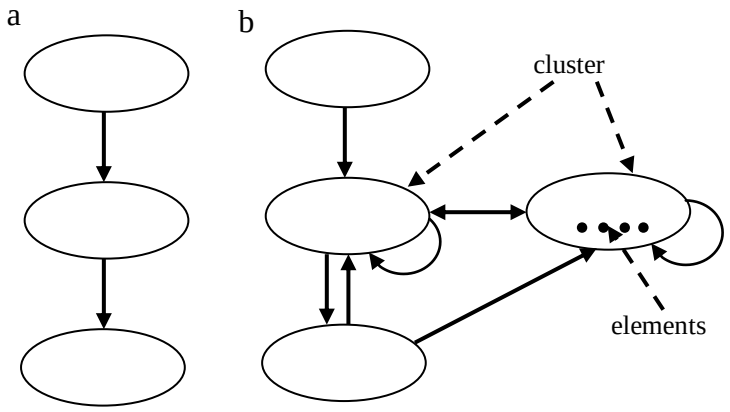

Figure 2.6 Structure difference between a hierarchy and a network: (a) a hierarchy; (b) a network

Source: Chung et al., 2005

2.5.3 Analytical Network Process (ANP) methodology

There are 4 steps of ANP that are:

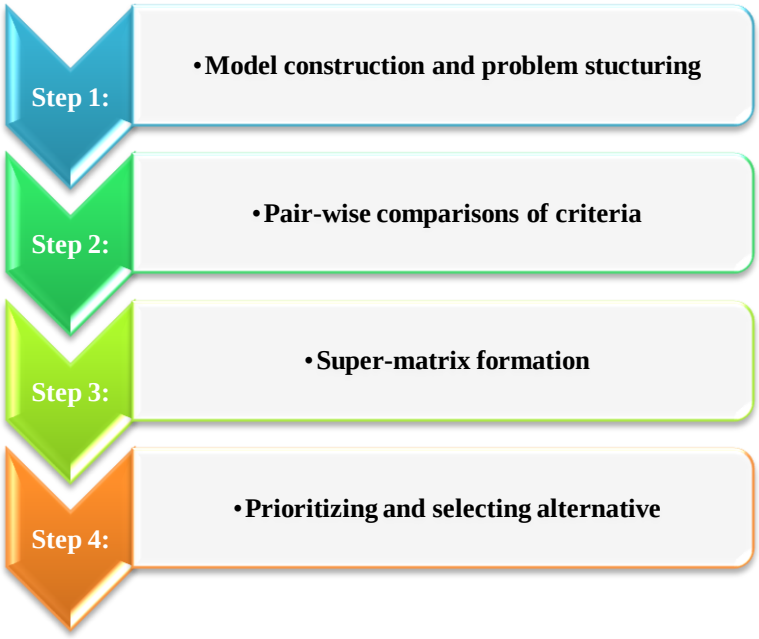

Figure 2.7 Steps of ANP study

Step 1: Model construction and problem structuring. The decision problem is clearly stated and decomposed into a network in this step. The elements which consists of criteria and sub-criteria can be identified by the opinion of experts through Modified Delphi method.

Step 2: Pair-wise comparisons of criteria. For this step, the decision maker is asked to respond to the relative weighting of each criterion through the pairwise comparison matrix A, for example in Table 2.4. Saaty's 1–9 scale (Saaty,1996) was utilized to compare an answer, in which, 1 indicates ''equal importance", 3 indicates ''moderate importance", 5 indicates ''strong importance", 7 indicates ''very strong importance", and 9 indicates ''extreme importance" as Table 2.5. For all experts, a synthesized pairwise comparison matrix will be presented by the geometric mean method from aggregating of expert's opinions in AHP/ANP (Aczel and Saaty, 1983; Saaty, 2005; Xu, 2000).

The geometric mean of a data set $\{a_1 a_2 \cdots a_n\}$ is given by:

$$\left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 a_2 \cdots a_n}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad (2.1)$$

Table 2.5 Scale of relative importance

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	When compromise is needed

Saaty, 1980

Table 2.6 Pairwise comparison matrix A.

	C	D	E	F	Q	U
C	1	1/9	1	1/3	1/7	1/4
D	9	1	9	2	1	2
E	1	1/9	1	1/8	1/9	1/7
F	3	1/2	8	1	1/4	1
Q	7	1	9	4	1	2
U	4	1/2	7	1	1/2	1

After each criterion is compared, a paired comparison matrix (A) is formed.

The matrix A can be defined by

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \tag{2.1}$$

where n is the order of matrix.

Then the consistency property in the pairwise comparison is investigated by the process as follows (Saaty, 2005):

1) Structure the normalized pairwise comparison matrix A_1

$$A_1 = \begin{bmatrix} a'_{11} & a'_{12} & \cdots & a'_{1n} \\ a'_{21} & a'_{22} & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & a'_{nn} \end{bmatrix}, \tag{2.2}$$

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \text{ for i, j = 1, 2, …, n,} \tag{2.3}$$

2) Calculate the eigenvalue and the eigenvector

$$W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix}, and \quad W_i = \frac{\sum_{i=1}^{n} a'_{ij}}{n} \quad for\ i = 1, 2, \dots, n, \tag{2.4}$$

$$W' = AW = \begin{bmatrix} W'_1 \\ W'_2 \\ \vdots \\ W'_n \end{bmatrix}, \tag{2.5}$$

$$and \quad \lambda_{max} = \frac{1}{n}\left(\frac{W'_1}{W_1} + \frac{W'_2}{W_2} + \cdots + \frac{W'_n}{W_n}\right), \tag{2.6}$$

where W is the eigenvector, w_i is the eigenvalue of criterion I, and λ_{max} is the largest eigenvalue of the pairwise comparison matrix.

3) Check the consistency property.

Where CI is the consistency index, CR is the consistency ratio, λ_{max} is the largest eigenvalue of the pairwise comparison matrix, n is the matrix order, and RI is the random index. Table 2.5 shows a set of recommended RI values proposed by Saaty (2005). When CR values are > 0.1 for a matrix larger than 4 x 4, it indicates an inconsistent judgment. Decision makers should revise the original values in the pairwise comparison matrix. Since CR is < 0.1, the comparison matrix in the example is consistent. As the comparison matrices for sub criteria are in accordance with their respective upper level dimensions (cost, quality, flexibility, time, innovativeness, and collaboration), their eigenvectors and consistent ratios are obtained.

1) Calculate CI

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{N}}{\mathrm{N}-1} \tag{2.7}$$

Where

λ_{max} = the largest eigenvalue of the pairwise comparison matrix.

N = no. of criterion

2) Calculate CR

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{2.8}$$

where

RI = random index that comes from Table 2.7.

Table 2.7: Random index

N	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Yang et al., 2009.

Step 3: Super-matrix formation. In the ANP, Saaty introduces the super matrix concept that is similar to Markov chains; it is used to handle the interdependence characteristics among criteria and sub-criteria. The local priority vectors are entered to the super-matrix aimed to obtain global priorities. A partitioned matrix is a super-matrix, where each matrix segment represents a relationship between two nodes (criteria or sub-criteria) in a system Saaty and Sarkis (1999). Then, give the clusters of a decision system be C_k, k = 1, 2, …, n, and each cluster k has m_k elements, denoted by e_{k1}, e_{k2}, …, e_{kn}. The local priority vectors obtained in Step 2 are grouped and put in the suitable position of supper-matrix depend on the influence flow from one cluster to another, or from a cluster to itself, as in the loop. Figure 2.6 is a standard form for a super-matrix (Saaty, 1996).

$$
W = \begin{array}{c} \\ c_1 \\ \\ \\ \\ c_k \\ \\ \\ \\ c_n \\ \\ \end{array}
\begin{array}{c}
\begin{array}{cccccccccccccc} e_{11} & e_{12} & \dots & e_{1m1} & \dots & e_{k1} & e_{k2} & \dots & e_{k\,mk} & \dots & e_{n1} & e_{n2} & \dots & e_{n\,mn} \end{array} \\
\begin{bmatrix}
W_{11} & \cdots & W_{1k} & \cdots & W_{1n} \\
\vdots & & \vdots & \vdots & \vdots \\
W_{k1} & \cdots & W_{kk} & \cdots & W_{kn} \\
\vdots & & & \vdots & \\
W_{n1} & \cdots & W_{nk} & \cdots & W_{nn}
\end{bmatrix}
\end{array}
$$

Figure 2.8 A standard form for a super-matrix

Source Yazgan et al., 2010

For an example, Figure 2.5a, represents the representations of the super-matrix for a hierarchy with three levels is as follows (Saaty, 1996):

$$W = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & 0 & 0 \\ 0 & W_{32} & I \end{bmatrix}. \quad (2.7)$$

Where W_{21} is a vector that represents the impact of the objective on the criteria, W_{32} is a matrix that represents the impact of criteria on each alternative, I is the identity matrix, and all of zeros corresponding to those elements that have no influence. However, if the criteria are interrelated among themselves, then the hierarchy is replaced by a network shown in Figure 2.5b. The presence of the matrix element W_{22} of the super-matrix W_n can be represented the interdependency of the super-matrix and it would be (Saaty, 1996):

$$W_n = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{bmatrix}. \quad (2.8)$$

Note that if there is an interrelationship of among elements within a cluster or between two clusters, then any zero value in the super-matrix can be replaced by a matrix. As there usually is interdependence among clusters in a network, the columns of a super-matrix may outcome to more than one. However, the super-matrix should be modified so that each column of the matrix sums to unity. The recommendation approach relates determining of the relative importance of the cluster as the controlling component by Saaty and Sarkis (1999). Raising a matrix to powers gives the influences of long term relative to the elements on each other. Obtaining a convergence on the importance weights that the weighted super-matrix is raised to the power of 2k+1, where k is an arbitrarily large number, and it is called the limit super-matrix (Saaty, 1996). The form of the limit super-matrix has similar to the weighted super-matrix, but all the columns of the limit super-matrix are the same. Normalizing of each cluster in a super-matrix can be reached the final priorities of all elements,

especially where there is a relative few of the number of elements in the model, the final priorities can be calculated through using matrix operations.

Step 4: Prioritizing and selecting alternative. When the super-matrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of the alternatives in the normalized super-matrix. On the other hand, if a super-matrix only consisted of the clusters that are interrelated, then the additional calculations must be placed to obtain the overall priorities of the alternatives. The judgment of the calculations can give the best alternative by using matrix operations, and the largest overall priority among the alternatives should be selected. The limit supermatrix provides priorities of alternatives.