Prioritization of Supply Chain Reconfiguration Variables using Balanced Score Card and Analytic Network Process

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Supply chain reconfiguration has emerged as a key variable that determines the capability of supply chain to adjust itself in wake of risks or dynamic business environment. However, supply chain reconfiguration is dependent on several variables that need to be prioritized to focus resources for improvement. The study reported in this paper proposes a multi-criteria decision approach to prioritize the variables associated with supply chain reconfiguration. The novelty of the proposed model lies in its capability to integrate the dimensions of balance scorecard and analytic network process. The proposed model is evaluated for a case supply chain from retail sector.

Keywords: Supply Chain Management, Analytic Network Process, Multi-Criteria Decision Model, Balanced Scorecard

1. Introduction

In wake of variety of risks and dynamic business environment, supply chain reconfiguration has emerged as a key attribute. Several studies (Kaminsky et al. 2004; Storer et al., 2014; Varsei et al., 2014; Vidal and Goetschalckx, 1997) have described supply chain reconfiguration as a reshaping of resources. These studies considered it a strategic goal of firms and an operational competence for supply chain. In a crisis, a dramatic change in business paradigm will occur that would require restructuring or reconfiguration of the supply chain (Roh et al., 2014). Supply chain reconfiguration is not only a required attribute to manage supply chain risks, dynamic reconfiguration of the supply chain is needed to cope with changes in the demand and cost structure over time, because of variations in economic factors and the business environment (Wilhelm et al., 2013).

Balanced Scorecard (BSC) technique is one of the most widespread performance evaluation approaches, and it considers both non-financial elements and financial elements (Lu et al., 2018). BSC framework provides performance management organized into four areas or perspectives, financial, customer, internal business processes, and innovation and learning (Kaplan and Norton, 1992a). Each area includes a number of leading and lagging indicators (Anjomshoae et al., 2017). Leading indicators are drivers of incremental change that affect the outcome measure while lagging indicators measure outcomes by showing the result of the strategy (Anjomshoae et al., 2017). The four BSC perspectives are interlinked to facilitate the evaluation of corporate strategy (Modak et al., 2019). In line with BSC, supply chain management literature suggests that non-financial and financial indicators are equally important for operational management (Tseng et al., 2015).

The research presented in this paper proposes a multi-criteria decision model to prioritize supply chain reconfiguration variables. After Introduction, Section 2 provides extant literature on balance scorecard and other issues related to the model. Section 3 proposes a systematic ANP procedure and Section 4 demonstrates the application of the proposed model to a case study. Finally, the study draws conclusions and indicates directions for future research.

2. Literature Review

To establish an adequate analytical network, this paper reviews the extant literature related to balanced scorecard, analytic network process (ANP) models in supply chain, integrated ANP-BSC models and supply chain reconfiguration.

2.1 Balanced Scorecard (BSC)

The balanced scorecard (BSC) is a widely used system to measure the performance of organizations across four different perspectives: financial, customer, internal business processes, and innovation and learning (Kaplan and Norton, 1992). The BSC framework was initially developed by Kaplan and Norton (1992, 1996a), as a strategic performance management tool that allows organizational managers to assess a firm’s action plan and imagine possible future positions (Cebeci, 2009). Traditional financial measures often overemphasized short-term financial performance. BS Callows managers to develop a more comprehensive view of operations (Brewer and Speh, 2000; Chavan, 2009), by integrating and maintaining a balance between financial and non-financial measures, looking at the organization’s long-term objectives (Hafeez et al., 2002; Wang et al., 2012). It aims to clarify and translate the vision and strategy of the organization, and communicate and associate this with objectives and strategic measures (Ferreira et al., 2016; Kaplan and Norton, 1996b). It can help firms to plan goals, align strategic initiatives and improve feedback and strategic learning (Ferreira et al., 2016; Kaplan and Norton, 1996b).

2.1.1 Financial Perspective

The financial perspective includes traditional financial performance measures, which are related to firm profitability. Financial measures are considered to occur in one of three stages: rapid growth (early life cycle stage of business), sustain (focus on attracting investment and reinvestment) or harvest (mature phase of the life cycle) (Kaplan and Norton, 1996a). These three stages can be combined with three financial themes, revenue growth and mix (expanding product and service offerings), cost reduction/productivity improvement (lowering the direct costs of products and services) and asset utilization (reduce working and physical capital levels) (Callado and Jack, 2015; Okongwu et al., 2015).

2.1.2 Customer Perspective

The customer perspective focus on customer satisfaction and market segments. Managers monitor the performance of operational units in satisfying target segments (Modak et al., 2019). Kaplan and Norton (1996a) suggested that generic measures such as customer satisfaction, retention, acquisition, and profitability could be understood by measuring product/service attributes. Customer relationship and image and reputation could be customized to target customer groups.

2.1.3 Internal Process Perspective

The internal process perspective emphasizes identifying new processes for some of the operational activities responsible for satisfying target customers. The activities, such as value chain activities, help the business to meet current and future needs of stakeholders (Modak et al., 2019). Common measures of value chain activity may include new products, new processes, productivity per business unit, product turnover, after-sales activity, operational cycle, suppliers, waste, flexibility, response time to customer, delay in delivery, responsiveness of suppliers, storage time, and information/integration of materials (Callado and Jack, 2015).

2.1.4 Learning and Innovation Perspective

The learning and innovation perspective focuses on the infrastructure (people, systems and organizational procedures) required to create long-term growth and improvement. The measures are related to employee satisfaction, investment in training and career growth of employees, investment in information systems or technology, employee capability, managerial efficiency, innovation management, number of complaints, and risk management (Callado and Jack, 2015; Lee et al., 2008; Tjader et al., 2014).

2.2 Balanced Score Card in the Supply Chain Management

Several studies have suggested utilizing the BSC framework through the application of a multi-criteria decision making (MCDM) approach (Abran and Buglione, 2003; Lee et al., 2008; Yüksel and Daĝdeviren, 2010). MCDM is a structured approach that helps to solve decision problems with multiple criteria (Majumder, 2015). It has a wide variety of applications and provides stepping-stones toward solving any problem where a significant decision needs to be made (Ishizaka and Nemery, 2013). A number of researchers have applied BSC methodology to study issues related to supply chain management (Brewer and Speh, 2000; Callado and Jack, 2015; Chia et al., 2009; Ferreira et al., 2016; Hult et al., 2008; Nouri et al., 2019; Okongwu et al., 2015; Park et al., 2005; Tan et al., 2016; Tseng et al., 2015). Studies have used the BSC to assess the performance of the supply chain (Brewer and Speh, 2000; Ferreira et al., 2016; Park et al., 2005; Tan et al., 2016), the roles of the supply chain (Callado and Jack, 2015), and supply chain orientation (Hult et al., 2008). The BSC framework emphasizes the inter-functional and inter-firm nature of the supply chain, recognizing the need for and increasing the chances of a balanced management approach to supply chain management (SCM) goals. However, using the BSC as a system of strategic management is complicated because there are many different strategic path slinking supply chain management practices with tangible assets and financial performance (Okongwu et al., 2015). This may lead the firm to remain focused on traditional financial measures coupled with customer satisfaction (Chia et al., 2009).

Studies about the inclusion of sustainable SCM (SSCM) in the BSC have used different dimensions. For example, Nouri et al. (2019) used financial, stakeholder, supply chain, and learning, growth, and innovation dimensions. They interviewed a panel of experts and found that the most important factors in each dimension were cost (financial), customer satisfaction (stakeholders), flexibility (supply chain), and individual capabilities (learning, growth and innovation). Tseng et al. (2015) assessed the same four options. They concluded that the stakeholder aspects received more attention than the other aspects. The top five criteria were green design, corporate sustainability, strategic planning for environmental management, supplier cost saving initiatives and market share.

Table 1 *Balance Score Card in Supply Chain*

Author(s)	Year	Category	Specific Aims	Performance Indicators	Sample	Methodology	Finding
Callado and Jack	2015	Supply chain roles	The evolution of supply chain performance through BSC	Two group of variables:4 SC roles variables and 49 performance indicators	121 agribusiness companies in Brazil	Survey	Customer satisfaction was the single metric present within the BSC framework for all supply chain roles
Ferreira, Silva, Azevedo	2016	Supply chain performance	Evaluation of environmental performance of supply chain	Financial, suppliers, processes, learning and innovation	First tier suppliers from automotive industry	Case Study	Proposed a decision support tool to define actions to be taken in order to improve the global environment performance of the supply chain
Okongwu, Brulhart, Moncef	2015	Supply chain management practices	Investigation of the casual linkage between supply chain management practices and performance	Supplier partnership, customer relationship, information sharing, information quality	450 French industrial firms	Survey	They found that there are strategic paths of different nature that links the supply chain management practices with intangible assets to financial performance
Hult, Ketchen, Adams, Mena	2008	Supply chain orientation	To examine the links between supply chain orientation and performance	customer orientation, competitor orientation, value chain orientation, supplier orientation, logistics orientation,	129 firms	Survey	They found that supply chain capability has a direct positive effect on the four balance scorecard outcomes

				operation orientation			
Chia, God, Hum	2009	Supply chain entities	Examine what senior supply chain executives measure and how they perceive performance measurement from a BS perspective	15 variables, some of them are return on investment, gross revenue, profit before tax, cost reduction, market share, customers retention, customer satisfaction, quality of services, new services implemented per year, on time delivery, waste reduction, employee satisfaction	113 responses from logistics firms, manufacturers, IPOs, retailers	Survey	They found that firms remain focused on transaction financial measures with customer satisfaction measurement
Brewer and Speh	2000	Supply chain performance	To develop a framework for assessing supply chain performance using balance scorecard	End customer benefits, SCM goals, SCM improvement, financial benefit	2 firms (Campbell Soup, Sport Obermeyer)	Scenarios	Framework developed emphasizes the inter functional and intrafirm nature supply chain, recognizes the needs and increase the chance of balance management approach to achieve SCM goals
Tan, Zhang, Khodaverdi	2016	Supply chain performance	analyze the efficient and inefficient levels of service performance	Physical aspects, reliability, customer relationship through personal interaction, problem solving, customer perception towards service, number of customers	Ten automobile dealers	Survey	They found that dealers are inefficient in learning about customer growth that help dealers to transform from inefficient into efficient.

				serviced per day, profit, order processing time, complaints handled			
Tseng, Lim, Wong	2015	Sustainable supply chain management	The assessment of supply chain sustainability and performance	sustainability, internal operations, learning and growth, and stakeholder	A Taiwanese electronic manufacturing focal firm	Case study	They found that the top ranking is the stakeholders aspects and the top five criteria are green design, corporate sustainability, strategic planning for environmental management, supplier cost saving initiatives and market share
Nouri, Nikabadi, Olfet	2019	Sustainable service supply chain	The assessment of supply chain sustainability and performance in service supply chains	Financial dimension, stakeholder dimension, supply chain dimension, learning, growth and innovation dimension	Interview with panel of experts	Survey	They found that the cost from financial perspective, customer satisfaction from stakeholders perspective, are flexibility from supply chain perspectives, and the individual capabilities from learning, growth and innovation perspectives are the most important factors
Park, Lee, Yoo	2005	Supply chain performance	The design of balance supply chain scorecard	Profit, revenue, cost structure, use of assets, product leadership, customer relationship, corporate image,	Three SCM related	Case study	They found that the importance of the measures significantly depends on the product characteristics

				efficiency of manufacturing process, inventory management, delivery efficiency, flexibility, new product development, sourcing leadership, collaboration with partners, purchase order transaction efficiency, intangible capital				

2.3 Analytic Network Process (ANP) and Supply Chain Management

Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) are the most-frequently used MCDM approaches in the supply chain context. AHP is a hierarchy-structured technique introduced by Saaty (1980), used to assess, concentrate, compare, and evaluate the relative importance of criteria in a decision (Vinodh et al., 2017). However, it has some drawbacks, so Saaty (1996) introduced ANP to overcome these. This is an extension of AHP that allows researchers to examine the interdependencies among different criteria (Forman, 1996; Hashemi et al., 2015). ANP can therefore assess complex interaction effects among the components within the decision criteria. This allows a better representation of complex decision problems. ANP is a comprehensive multidimensional network structure technique that allows decision-makers to assess, concentrate, compare, and evaluate the relative importance of different criteria on different components of a decision, including problem objective, criteria, sub-criteria, alternatives and their interaction with and between groups (Saaty, 2001).

ANP has been extensively used in the SCM literature. For example, it has been applied to identifying alternative characteristics of trust among buyer and supplier transactions (Agarwal and Shankar, 2003), off shoring and outsourcing decisions (Dou and Sarkis, 2010), green supply chain (Büyüközkan and Çifçi, 2012a, b; Chen et al., 2012), supply chain competition (Joshi et al., 2013), supply chain strategic planning (Choudhury et al., 2004), supply chain intelligence (Soliman el al., 2005), and supply chain risk management (Xia and Chen, 2011). In all these studies, ANP was used to examine a minimum of three alternatives to look at the relationships between them and rank them in the decision. It therefore allowed managers to implement successful green supply chain management by prioritizing green suppliers and systems (Büyüközkan and Çifçi, 2012a, b), identify trust characteristics for an e-enabler supply chain system (Agarwal and Shankar, 2003), supply chain sustainability (Faisal et al., 2017) and identify supply chain competitiveness factors (Joshi et al., 2013). Researchers have also used ANP to select the appropriate decision for supply chain risk (Xia and Chen, 2011;Faisal et al., 2007) providing a strategic decision model to help practitioners to identify suitable risk management tactics (Xia and Chen, 2011).

Studies have also integrated ANP with other MCDM models, including Decision Making Trial and Evaluation Laboratory (DEMATEL) to evaluate supply chain performance. Hung (2011) and Wu et al. (2017) studied the improvement of competitive advantage in supply chain planning and supply chain agility. They found that supply chain management time and flexibility were the most important components in improving competitive advantage. The Fuzzy Decision Making Trial and Evaluation Laboratory (FDEMATEL) has also been used with ANP to calculate the causal relationship and level of mutual effect, building on the green supply chain (Büyüközkan and Çifçib, 2012; Kusi-Sarpong et al., 2016). Tuzkaya et al. (2011) used the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) to examined the Turkish white goods industry. They found that the warehousing cost was the main factor affecting collection period length and that transportation cost minimization was the most important factor for the Centralized Return Center CRC and Manufacturing Facilities MF assignments.

Other techniques have also been used with ANP to assess SCM. These include Quality Function Development (QFD) (Lam and Dai, 2015), Zero-One Goal Programming (ZOGP) (Büyüközkan and Berkol, 2010), Grey System Theory (GST, (Dou et al., 2014) Fuzzy Goal Programming (FGP) (Hung, 2011) , Data Envelopment Analysis (DMA) (Kusi-Sarpong et al., 2016), Multi Objectives Mathematical Programming method (MOMP) (Kirytopoulos et al., 2010), Fuzzy Set Theory (FST) (Wu et al., 2017), and Fuzzy Analytical Network Process (FANP) (Büyüközkan and Çifçib, 2012). All of these techniques have helped researchers and participants to solve complete decision-making problems, such as supplier selection decisions (Dou et al., 2014; Kirytopoulos et al., 2010), off shoring and outsourcing for sustainable supply chain management (Dou and Sarkis, 2010), and supply chain strategic planning (Choudhury et al., 2004).

2.4 Integration of BSC and ANP

A limited number of studies have used BSC with MCDM models to evaluate supply chain performance. Shafiee et al., (2014) and Moons et al., (2019) used both ANP and BSC to evaluate the performance of supply chain management to reach, sustain, and improve the logistics process. The results obtained for different supply chain performance indicators (i.e. quality, time, financial, productivity/organization) allowed participants to diagnose processes in real-world industries and propose improvement and innovation plans. Bhattacharya et al. (2014) demonstrated a green supply chain framework developing ANP to determine rank priority from comparative judgements in a UK setting. They used the Green Balance Scorecard Gr BSC method to assess performance indicators for the manufacturing industry.

Modak et al. (2019) used ANP and BSC to determine the best decision for outsourcing. The approach was used to evaluate the relative benefits of a strategic alliance, outsourcing and in sourcing. A study by Dev et al. (2019) applied an integrated approach combining intuitive fuzzy ANP and BSC to determine the decision criteria related to visualization of big data architecture. These criteria and sub-criteria were evaluated to give relative weights.

Table 2 *ANP-BSC Studies*

Author(s)	Year	Category	Specific Aim	Performance Indicators	Sample	Methodology	Techniques	Finding
Moons, Waeyenbergh, Pintelon, Timmermans, Ridder	2019	Operating room supply chains	Evaluate the efficacy of logistics processes in operating rooms	Quality, time, financial, productivity/ organization	Hospital logistics experts and managers	Interviews	ANP, BSC	Quality is the indictor to improve the inventory management whereas productivity is the contribution factor for distribution
Modak, Ghosh, Pathak	2019	Decision making	Propose an integrated approach for selection of best outsourcing strategy	strategic alliance, outsourcing and in sourcing	Coal mining organization in India	Case study	ANP, BSC	They found that strategic alliance is the best sourcing strategy followed by outsourcing and in sourcing
Dev, Shankar, Gupta, Dong	2019	Big data	Propose an approach to visualize a big data architecture conceptual framework	Forecasting error, review period, lead time, order size, service level, aggregate demand	Information from RFID network	Scenarios	DES, FANP, TOPSIS	The proposed model can be used as a decision support tool by the companies to evaluate their KPIs in a real-time dynamic system
Shafiee, Lotfi, Saleh	2014	Supply chain performance	Evaluate the overall performance of the supply chain by means of the BSC and DEA model	Fifteen indicators like return on investment, gross revenue, profit before tax, saving by supplier initiatives	Iranian food industries	Case study	BSC, DEA, DEMATEL	Found that nine DMU efficient, while the other 11 DMU inefficient
Parkouhi and Ghadikolaei	2017	Supplier Selection	Propose an initial conceptual model for resilience supplier selection evaluation	Twelve variables like flexibility, quality, culture, joint growth, supplier technology	large industrial unit in wood and paper industry	Experts opinion	FANP, VIKOR	Variation in price, vulnerability, supplier's capacity limit, visibility, on time delivery most important sub-criteria in resilient supplier selection
Bhattacharya, Mohapatra,	2014	Green supply	Green supply chain	Organizational commitment,	Manufacturing industry in	Case study	CDM, ANP,	Organizational commitment

Kumar, Dey, Brady, Tiwari, Nudurupati		chain	performance measurement framework using an intra-organizational collaborative decision making approach	eco-design, green supply chain processes, social performance, sustainable performance	UK		GrBSc	received the highest weight of performance measurement followed by sustainable performance, eco-design, green supply chain processes, and social performance, respectively

2.5 Supply Chain Reconfiguration

An increasing number of firms, both national or multinational, currently face the problem of whether and how to reconfigure their supply chain or network (Lambiase et al., 2015). Case studies suggest that changing firms or supply chains is a non-linear process requiring re-planning and learning throughout the change effort to build capacity and capability for change (Van Hoek et al., 2010). There are two parameters that determine the reconfiguration of any supply chain: financial and technology. Financial capability is the money available to invest, which is necessary to reconfigure the supply chain. It is also possible to consider different technology, such as Decision Support System (DSS) and Direct Digital Manufacturing (DDM), as a function of activity location (Lambiase et al., 2013).

There have been a limited number of studies on change within logistics and supply chains. Reconfiguration of supply chain management is generally considered across two categories: restructuring and non-restructuring. Reconfiguration of supply chain with restructuring often occurs in response to natural risks and crises (Kinkel, 2012; Osman and Demirli, 2010; Ross, 2000). Reconfiguration of supply chain without restructuring often occurs when redesigning a product, reallocating chains, or inventory allocation (Dev et al., 2014; Mondragon et al., 2018; Wei and Wang, 2010). Supply chain reconfiguration may often need to be rapid. There are therefore few studies on the reconfiguration of supply chain management during unpredictable or rare events arising from the supply chain’s interaction with its environment, such as natural disasters, labor strikes, bankruptcy, fire, transportation, and terrorism. Supply chain reconfiguration requires consideration of nine characteristics:

2.5.1 The Objective of Reconfiguration

The objective of supply chain reconfiguration is usually either profit maximization or cost minimization (Hammami and Frein, 2014; Ross, 2000; Spicer and Carlo, 2007; Wilhelm et al., 2013). Supply chain reconfiguration needs to establish a balance between the supply chain reconfiguration cost (i.e. cost of replacing suppliers, and changing the transportation network) and supply chain operation cost (i.e. transportation cost, procurement cost, and manufacturing cost) (Guo et al., 2018). These costs can be either fixed or variable. Fixed costs are associated with facility charges including opening, closing, operating, expanding, and contracting. Variable costs mainly accrue from holding inventories and incurring backorders, outsourcing, and transportation. One study defined the objective function in terms of cash flow (Niroomand et al., 2012). It argued that reconfiguration cost and investment cost are the firm's negative cash flows and sales revenue and salvage value of removed capacity are its positive cash flows (Niroomand et al., 2012).

2.5.2 Number of Echelons in the Supply Chain

A supply chain consists of suppliers, plants, warehouses, distribution centers, and customers Wilhelm et al. 2013). Each reconfiguration alternative involves different suppliers, production, and distribution options for raw material, finished goods, and final products (Dev et al., 2014). The performance of each echelon is unique. Each provides a specific product and is linked with a viable transportation system that allows shipment from a facility in one echelon to another elsewhere (Wilhelm et al. 2013). Environmental turbulence can force firms to relocate their plants and distribution centers to be both competitive and cost-efficient (Lemoine and Skjoett-Larsen, 2004). It is therefore difficult to assess the number of echelons, facilities, and flows of product between facilities (Hammami and Frein, 2014).

2.5.3 Closing and Opening New Facilities

Redesigning supply chain may lead to the closure of existing facilities and opening of new ones. Many researchers have argued that the capacity of a facility usually remains stable over time (Canel et al., 2001; Klose and Drexel, 2005; Lee and Luss, 1987; Melo et al., 2006, 2009; Wilhelm et al., 2013). The capacity of any facility in the planning horizon cannot be contracted (Wilhelm et al., 2013). The cost of closing and opening facilities are still rarely considered. Hammami and Frein (2014) found that if the cost of closing a facility was more than 30,000 or 20,000 Euros the original site would probably be kept open. To cope with the complexity, firms need an intermediate step in the planning process. A multi-period planning horizon is a permanent stage for facility closing/opening and is necessary for capacity allocation (Hammami and Frein, 2014; Wilhelm et al., 2013).

2.5.4 Intermediate Processing Requirements

Intermediate product processing has a key role in redesigning the supply chain. It has recently become more important because globalization and outsourcing have increased the fluidity and complexity of supply chains (Kirkwood et al., 2005). Supply chain activities can have multiple locations for one or more activity (Kristianto et al., 2012). Intermediate products are therefore important for two reason. The first is that the final product can be kept near the customer site while the manufacturing of intermediate products is relocated elsewhere (Hammami and Frein, 2014). The second is that intermediate products can shift income by using transfer prices (Hammami and Frein, 2014).

2.5.5 Capacity Relocation Decision

Relocating capacity is often considered in supply chain redesign. It depends on the profitability of activities. Managers often first investigate whether it will be profitable to relocate some activities from existing to new sites (Hammami and Frein, 2014), either wholly or partially. Studies have found that including relocating capacity along with facility location, supplier selection, and physical flow size in decisions about supply chain reconfiguration can significantly improve profits (Hammami and Frein, 2014; Osman and Demirli, 2010).

2.5.6 Information Technology Integration

The most prominent driver behind reconfiguration is improved information and communication technology (ICT) (Lemoine and Skjoett-Larsen, 2004). Modern technology helps managers to reduce the number of suppliers (Mondragon et al., 2018). Involving ICT in reconfiguring the supply chain will increase the possibility of transferring information both geographically and between supply chain participants (Lemoine and Skjoett-Larsen, 2004).

2.5.7 Financial Factors

Taxation rate, exchange rate, and transfer pricing are the main global factors considered in previous studies (Hammami and Frein, 2014). These international dimensions help to explain differences in income and expenses during reconfigurations. Hammami and Frein (2014) found that exchange rate had a greater role in activity location decisions than tax rate. Transfer pricing has been studied around both supply chain redesign and supply chain decisions. It refers to the strategy for determining transfer price that buyer subsidiary has to pay for selling subsidiary to a given product (Perron et al., 2010). Shunko and Gavirneni,(2007) argued that transfer pricing is a powerful tool for shifting income to subsidiaries in lower tax countries and consequence increasing after tax profit of the supply chain. More examples also support the used of transfer pricing in increasing the income from high tax to low tax countries (Shunko et al., 2014; Lakhal et al., 2005).

2.5.8 Transportation Systems

Transport systems are important in reconfiguration of supply chains. The market requirement may force firms to reconfigure their supply chain to achieve customer requirements about time (Akanle and Zhang, 2008; Gosling et al., 2010; Lemoine and Skjoett-Larsen, 2004). The cost, system, and flexibility of transportation are the main factors affecting supply chain reconfiguration (Akanle and Zhang, 2008; Gosling et al., 2010; Lemoine and Skjoett-Larsen, 2004).

3. Proposed Methodology for Supplier Valuation/ Prioritization for Supply Chain Reconfiguration

Supplier evaluation for supply chain reconfiguration involves simultaneous consideration of multiple criteria, and thereby requires the application of multi-criteria decision-making (MCDM). Analytic hierarchy process (AHP) and analytic network process (ANP) are the two most important and popularly used multi-criteria decision-making (MCDM) methods that aid the decision maker to select the best choice under situations characterized by having more than one criterion (or multiple criteria). In recent times, AHP due to its strict hierarchy based approach is not a favored technique in solving real world problems that involves interdependence of criteria and sub-criteria. Therefore, ANP with its freedom of providing decision maker the choice of creating relationships among criteria and sub-criteria that simulate real world issues has emerged as a popular MCDM technique. ANP models the decision making problem as a network of criteria and alternatives grouped as clusters (Saaty, 2001). The major advantages of ANP method can be summarized as follows:

- ANP uses a network without the need to specify levels as in a hierarchy.
- All elements in the network can be related in any possible way, which means that a network can incorporate feedback and interdependent relationships within and between clusters.

Extant literature on the application of ANP (Giannakis et al., 2020; Das and Chakraborty, 2011), recommends a four step approach to model a multi-criteria decision situation. However, the last step of this suggested approach is related to the selection of an alternative. However, in our case the objective is to prioritize dimensions of supply chain reconfiguration and therefore we would adopt the three steps of the suggested methodology. These three steps are as follows:

Step 1: Define the Problem and Construction of the Network Model: The network model for this study including the interdependencies of criteria and sub-criteria were constructed utilizing Super Decisions software (Version 2.8) (https://www.superdecisions.com) as shown in Figure 1. In this Figure it should be noted that outer dependences are indicated by arrows while inner dependences are indicated by arcs.

Step 2: Pairwise Comparisons of the Clusters and Elements: Similar to AHP, pairwise comparisons are also carried out in ANP to determine the relative importance weights of elements in the network based on expert judgements made using Saaty's 1-9 fundamental scale (Saaty, 1990). According to Saaty, if element i has one of the numbers 1–9 assigned to it when compared with element j, then a reciprocal value is assigned to j; i.e., $a_{ij}=1/a_{ji}$, where $a_{ij}(a_{ji})$ denotes the relative importance of the i^{th} (j^{th}) element. Pairwise comparisons are made with respect to clusters and within clusters. To ensure the consistency of decision maker(s) judgements, consistency index is evaluated, compared with random index to obtain the value of consistency ratio (CR). A value of CR less than 0.1 indicates the consistency of judgement in pairwise comparisons (Simwanda et al., 2020).

Pairwise comparisons under ANP model are carried out with the support of experts with the knowledge in the area under study. In the present case, five experts were consulted, three from industry and two from academics. They were physically visited to apprise them and clarify about the criteria and sub-criteria. Later, their inputs were solicited regarding pairwise comparisons to create matrices. It can be expected that the experts in the focus group would have different values of pairwise comparisons. Previous research strongly suggests using a geometric mean in deriving the final values of pairwise comparison (Faisal et al., 2011;Giannakis et al., 2020) which was followed in the present research.

Step 3: Super matrix Formation: A super matrix is a partitioned matrix, where each sub matrix is composed of a set of relationships between two clusters. After pairwise comparisons and obtaining the local priority vectors associated with the elements, the priority vectors are entered into the appropriate columns of a matrix which illustrates the relative influences among elements in the system. This is called the unweighted supermatrix (Khan and Faisal, 2008; Simwada et al., 2020). Next step is to create a column stochastic matrix known as weighted super matrix. Finally, this weighted supermatrix is raised to limiting powers until the weights of elements converge to stable global priority weights. The result is known as limiting matrix and the final priorities in this matrix can be used to prioritize criteria and sub-criteria that impact a multi-criteria decision model (Promentilla et al., 2008).

3.1 Application of the Proposed Methodology to Case Supply Chain

The proposed methodology was applied to a case supply chain from retail sector. Due to econo-political risk that occurred in 2017, this supply chain had to face major disruptions. The first step is to develop the model considering the criteria and sub-criteria that can be utilized. In this case, the criteria were the dimensions of balance scorecard, namely customer, financial, internal business perspective, and innovation perspective. Further, supply chain reconfiguration dimensions were selected through a literature review and were classified under each balance scorecard dimension with the help of the experts. The network model is shown in Figure 1. This Figure also indicates various dependencies, inner and outer including cluster dependencies.

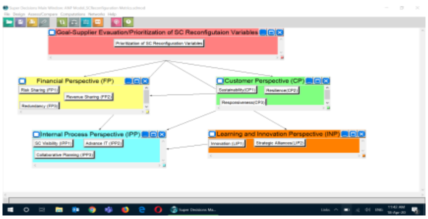

Figure 1 *Multi-criteria Decision Model for SC Reconfiguration Variables*

Pairwise Comparisons: First comparison was among the criteria of balance scorecard with respect to the goal. The values of this comparison are shown in Table 3. The last column of the Table shows the Eigen value of this pairwise comparison.

Table 3 *Pairwise Comparison of the Dimensions of Balanced Scorecard with Respect to Goal*

	Financial Perspective	Customer Perspective	Internal Process Perspective	Learning & Innovation Perspective	e-vector
Financial Perspective	1	1/2	2	5	0.29286
Customer Perspective	2	1	3	5	0.46472
Internal Process Perspective	1/2	1/3	1	4	0.17907
Learning & Innovation Perspective	1/5	1/5	1/4	1	0.06336

CR: 0.03672

The next pairwise comparison is for each of the dimension of the balanced score card with respect to their sub-dimension. There would be four pairwise matrices representing each dimension of the balance scorecard.

Table 4 *Pairwise Comparison 'Financial Perspective Sub-Dimensions' with Respect to Goal*

Financial Perspective	**FP1**	**FP2**	**FP3**	**e-vector**
FP1	1	1/3	3	0.25829
FP2	3	1	5	0.63699
FP3	1/3	1/5	1	0.10473

CR: 0.03703

Table 5 *Pairwise Comparison of 'Customer Perspective Sub-Dimensions' with Respect to Goal*

Customer Perspective	**CP1**	**CP2**	**CP3**	**e-vector**
CP1	1	1/4	1/6	0.08522
CP2	4	1	3	0.27056
CP3	6	1/3	1	0.64422

CR: 0.05156

Table 6 *Pairwise Comparison of 'Internal Process Perspective Sub-Dimensions' with Respect to Goal*

Internal Process Perspective	**IPP1**	**IPP2**	**IPP3**	**e-vector**
IPP1	1	5	3	0.63699
IPP2	1/5	1	1/3	0.10473
IPP3	1/3	3	1	0.25828

CR: 0.03703

Table 7 *Pairwise Comparison of 'Learning & Innovation Perspective Sub-Dimensions' with Respect to Goal*

Learning & Innovation Perspective	***FP1***	***FP2***	***e-vector***
LIP1	1	1/4	0.20000
LIP2	4	1	0.80000

CR: 0.0000

Finally, Table 8 and Table 9 provides pairwise comparisons that represent outer dependence, e.g. relationship between sustainability in customer perspective and strategic alliance in innovation perspective with the sub-dimensions of internal process perspective. Similarly, Table 10 provides outer dependence between resilience in customer perspective with the sub-dimensions of financial perspective.

Table 8 *Pairwise Comparison of 'Sustainability (CP1)' with Respect to 'IPP Sub-Dimensions'*

Sustainability	**IPP1**	**IPP2**	**IPP3**	**e-vector**
IPP1	1	6	3	0.65481
IPP2	1/6	1	1/3	0.09534
IPP3	1/3	3	1	0.24986

CR: 0.01759

Table 9 *Pairwise Comparison of 'Strategic Alliances (LP2)' with Respect to 'IPP Sub-Dimensions'*

Strategic Alliances	IPP1	IPP2	IPP3	e-vector
IPP1	1	2	1/4	0.19981
IPP2	1/2	1	1/5	0.11685
IPP3	4	5	1	0.68334

CR: 0.02365

Table 10 *Pairwise Comparison of 'Resilience (CP2)' with Respect to 'FP Sub-Dimensions'*

Resilience	FP1	FP2	FP3	e-vector
FP1	1	1/4	3	0.21764
FP2	4	1	6	0.69096
FP3	1/3	1/6	1	0.09140

CR: 0.05156

After all pairwise comparisons are completed and checked for consistency, the maximum eigenvalues and the corresponding eigenvectors of the pairwise comparison matrices are calculated to generate the super matrix.

Development of Super matrix

ANP uses super matrix to deal with the relationship of feedback and interdependence among the criteria. The super matrix allows a resolution of the effects of interdependence that exists between the elements of the system. The super matrix is a partitioned matrix, where each sub matrix is composed of a set of relationships between two levels in the graphical model. If no interdependent relationship exists among the criteria, the pairwise comparison value would be 0. In contrast, if an interdependent and feedback relationship exists among the criteria, then such value would no longer be 0 and an unweighted super matrix M will be obtained (Tseng et al., 2009; Faisal and Banwet, 2009).In an unweighted super matrix, its columns may not be column stochastic. To obtain a stochastic matrix (i.e., each column sums to one), multiply the blocks of the unweighted super matrix by the corresponding cluster priority. The super matrix must satisfy the principle of column stochastic, which means every column should add up to 1.

Table 11 also provides the final priority ranking for the case supply chain. It is clear that for this supply chain, responsiveness, revenue sharing, visibility are the top three variables that would impact supply chain reconfiguration

.

4. Conclusions

In this study, we proposed an integrated BSC-ANP approach for evaluating supply chain reconfiguration variables. Supply chain reconfiguration variables were identified from the extant literature and were grouped under the four dimensions of balanced scorecard with inputs from experts. A major contribution of the paper lies in its linkage of supply chain reconfiguration variables with a popular performance management framework. A key advantage of the model lies in its capability to simultaneously consider both qualitative and quantitative factors and consider their interdependencies, which is not possible to evaluate by any other statistical technique. The framework represents only one set of possible relationships and the ANP model may be enhanced through the inclusion of additional relationships. Therefore, in future studies, the robustness of the proposed model can be evaluated by considering supply chains from different sectors and including some other supply chain reconfiguration variables.

Table 11 *Unweighted, Weighted and Limiting Super Matrices*

	Unweighted Supermatrix	Weighted Supermatrix	Limiting Supermatrix	Financial Perspective			Customer Perspective			Internal Process Perspective			Learning & Innovation			
				FP1	FP2	FP3	CP1	CP2	CP3	IPP1	IPP2	IPP3	LIP1	LIP2	Priority Vector	**Rank**
Goal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
FP1 Risk Sharing	0.25828	0.07564	0.08471	0.0000	0.0000	0.0000	0.0000	0.2176	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.084706	**5**
FP2 Revenue Sharing	0.63699	0.18655	0.22485	0.0000	0.0000	0.0000	0.0000	0.6910	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.224849	**2**
FP3 Redundancy	0.10473	0.03067	0.03467	0.0000	0.0000	0.0000	0.0000	0.9140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.034673	**8**
CP1 Sustainability	0.08522	0.03960	0.03257	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.032568	**9**
CP2 Resilience	0.27056	0.12573	0.10340	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.103396	**4**
CP3 Responsiveness	0.64422	0.29938	0.24628	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.246197	**1**
IPP1 SC Visibility	0.63699	0.11406	0.12346	0.0000	0.0000	0.0000	0.6548	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1998	0.123455	**3**
IPP2 Advance IT	0.10473	0.01875	0.02340	0.0000	0.0000	0.0000	0.0953	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1169	0.023398	**10**
IPP3 Collaborative Planning	0.25828	0.04625	0.07465	0.0000	0.0000	0.0000	0.2498	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6833	0.074655	**6**
LIP1 Innovation	0.20000	0.01267	0.01042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.010420	**11**
LIP2 Strategic Alliances	0.80000	0.05069	0.04168	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.041682	**7**
Final Priority Ranking				**5**	**2**	**8**	**9**	**4**	**1**	**3**	**10**	**6**	**11**	**7**		

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