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Multi-attribute Performance Models for Small Manufacturing Enterprises

Madani Abdu Alomar
University of Windsor

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By

Madani Abdu Alomar

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Multi-attribute Performance Models for Small Manufacturing Enterprises

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Madani Abdu Alomar

APPROVED BY:

____
D. Alwerfalli, External Examiner
Lawrence Technological University

____
X. Guo
Odette School of Business

____
G. Zhang
Department of Mechanical, Automotive & Materials Engineering

____
H. ElMaraghy
Department of Industrial and Manufacturing Systems Engineering

____
Z. Pasek, Advisor
Department of Industrial and Manufacturing Systems Engineering

June, 2015

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I. Co-Authorship Declaration

I hereby declare that this thesis incorporates material that is the result of joint research. *In all cases, the key ideas, primary contributions, experimental designs, data analysis, and interpretation were performed by the author with the contribution of Dr. Z. Pasek, the advisor.*

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Chapter 2&3	Alomar, M. (2013). Improving performance of SMEs using SCOR and AHP methodology. Proceedings from the *2013 Winter Simulation Conference: Simulation: Making Decisions in a Complex World*.	*Published*
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Chapter 3&4	Alomar, M., & Pasek, Z. (2014). Improving performance of SME'S using supply chain. Proceedings from *International Symposium of the Analytic Hierarchy Process 2014*.	*Published*

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ABSTRACT

Nowadays, there are huge environmental changes in the business world. These changes have resulted in tremendous growth and opportunities for new markets but also in challenges that threaten the operations and survival of firms. These competitive pressures are driving firms to re-evaluate their competitive strategies, supply chains, and manufacturing technologies in order to improve performance and survive long term. Small and medium-sized enterprises also face these challenges, which influence their operations and existence. They are significantly constrained by remarkable limitations in terms of financial resources as well as non-financial factors, such as informal strategic decisions and actions. Reports have revealed that small enterprises are vulnerable to failure. Only around 50% of them in Canada and the United States survive for more than five years.

Focusing on financial measures alone is not a good strategy for guaranteeing the long term success of a business. The absence of objective and formal strategic decisions and performance measurement systems in small enterprises increase their chances of failure. Therefore, models have been developed that assess and translate informal and qualitative in small enterprises into measurable, quantitative data. This allows for the evaluation and measurement of decisions and actions, which increases the chances of success for a small enterprise. Using the multi-criteria decision methodology (MCDM) allows for the following: integrating and linking various levels of decision-making and processes, converting subjective information into objective decision making, executing individual business preferences, and ranking strategic attributes and business processes.

An analytical hierarchy process approach was first used to develop a simple model. Using the case of a small manufacturing enterprise, it was found that the business did not emphasize financial measures alone; they also paid attention to non-financial measures, such as reliability and responsiveness. It was observed that the business was willing to rank strategic attributes and supporting business processes each time there was a change in the external environment. Finally, an analytical network process approach to express the links and effects among the supply chains of a small business were established, and an overall business performance formula was created.

DEDICATION

This dissertation is dedicated to my children: Lana, Toleen, and Faris. I give my special and deepest expression of love and appreciation to my wife, Alaa, for the encouragement that she gave and the sacrifices she made during my graduate program. I am truly thankful for having them in my life. This work is also dedicated to my parents, Abdu Omar, may Allah have mercy on him, and Ghalia, who has always loved me unconditionally and whose good examples have taught me to work hard for the things I aspire to achieve.

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Foremost, I would like to express my sincere gratitude to my advisor, Dr. Zpigniew J. Pasek, for his continuous support during my PhD program, and for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me throughout all the research and writing processes of this dissertation. Besides my advisor, I would like to thank the rest of my thesis committee, Dr. Guoqing Zhang, Dr. Hoda ElMaraghy, and Dr. Xiaolei Guo, for their encouragement, insightful comments, and challenging questions. My sincere gratitude also goes to Dr. Waguih ElMaraghy, for his valuable advice that positively contributed to the production of high quality research. Last, but not least, I would like to thank my parents, my family, and my friends for supporting me throughout my work and life.

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LIST OF ABBREVIATIONS/SYMBOLS

ABC	Activity based costing
AHP	Analytical hierarchy process
ANP	Analytical networking process
BSC	Balance scorecard
C_{11}	Cost of source
C_{12}	Cost of make
C_{13}	Cost of deliver
C_{14}	Cost of return
CI	Consistency index
CR	Consistency ratio
CSR	Cost saving ratio
DIPM	Dynamic integrated performance measurement
ES	Efficient strategy
ESCS	Efficient supply chain strategy
GDP	Gross domestic product
MCDA	Multi-criteria decision analysis
MCDM	Multi-criteria decision-making
N_i	Total number of indicators belong to criteria i
OPM	Organizational performance measurement
PMM	Performance measurement and management
PMS	Performance measurement system
R_1	Number of orders delivered within agreed time
R_2	Total number of orders
R_{ijk}	Rating of decision alternative k and for indicator j of criteria i
RI	Random index
RS	Responsive strategy
RSCS	Responsive supply chain strategy
SCOR	Supply chain operations reference

SCPM	Supply chain performance measurement
S_k	Overall decision of alternative k
SME	Small and medium-sized enterprise
TOC	Theory of constrains
TSCC	Total supply chain costs
X_1	Cost saving ratio or CSR
X_2	Order fill rate
X_3	Response rate
W_1	Value assigned for cost/cost saving ratio
W_2	Value assigned for reliability/order fill rate
W_3	Value assigned for responsiveness/response rate
W_i	Relative weight of criteria i
W_{ij}	Relative weight of indicator j of criteria i
λ_{max}	Principle eigenvalue

CHAPTER 1

BACKGROUND OF THE RESEARCH

Since the beginning of last decade of the twentieth century, there have been huge environmental changes in the business world. On one hand, these changes have resulted in tremendous growth and opportunities for new markets, and on the other, they have resulted in problems and challenges of growing complexity that have threatened the operations and survival of firms. These competitive pressures are driving firms to continuously re-evaluate their competitive strategies, supply chains, and manufacturing technologies in order to improve performance, be more competitive, and survive long term (Alomar and Pasek, 2013).

Small and medium-sized enterprises (SMEs) play significant roles in achievement of national competitive advantages worldwide by providing a method for the creation of employment and the generation of wealth. Nevertheless, small enterprises are not exempted from external pressures. They face the same global turbulences and challenges that other enterprises face, which in turn, influence their operations and existence. Moreover, they are significantly constrained by remarkable limitations, including financial resources, manpower and managerial skills, weak to moderate bargaining power against customers and suppliers, ‘fire-fighting’ strategies, informal decisions and actions, and shallow organizational structures.

Studies revealed that small businesses are extremely susceptible to failure; about 50% of small businesses in Canada and 53% in the United States fail to survive for more than five years. In reality, these survived enterprises successfully maintained their competitive advantages in their relevant markets (Industry Canada, 2013).

Several researchers have linked the success of businesses to the type of performance measurement system they use and to the successful design and implementation of those measurement systems. Other researchers have considered strategic performance measurement systems as a means to attain competitive advantages, continuous improvement, and the ability to respond to the changes (Cocca & Alberti, 2009). However, prior studies have found that the focus of many small enterprises is primarily on financial indexes. In 2001, Hudson and others conducted an empirical study on the implementation of performance measurement systems in small and medium-sized enterprises. The researchers found that all companies in the study had a surplus of financial measures, but their measurement systems were not derived from strategy, were often unclear with complex or obsolete data, and were historically focused with some outdated measures (Hudson, et al., 2001). An empirical survey conducted on eighty-three Danish enterprises found that 50% of them had either only one performance indicator, such as cost, or no performance indicator in place at all (Hvolby & Thorstenson, 2001).

Although a few multi-dimensional models of enterprise performance have existed for decades, previous studies have revealed that the majority of small and medium-sized enterprises fail to implement these performance measurement systems, and many of them maintain only financial measures. For example, a study about Canadian manufactures revealed that about 70% failed to implement well-known strategic performance measurement models, such as the balance scorecard model (Gosselin, 2005). The failure to implement strategic performance measurement systems in SMEs is mainly due to the characteristics and limitations of small and medium sized enterprises or a result of the complexity of the measurement framework and the improper implementation of the model. Hudson (2001) proposed that there are various obstructions to the use of performance measurement systems in SMEs. The failure to use them is basically a result of the development process being excessively concentrated on assets and resources and too strategically focused. This conflicts with the limited resources of SMEs and the more dynamic, emergent strategy styles found in SMEs (Hudson, 2001). These issues are intensely problematic because building up a strategic performance measurement system is a fundamentally long term process, and it unambiguously obliges the subsequent measures to be strategically focused. Consequently, numerous SMEs do not have the benefits of executing a multi-dimensional, money related, and non-monetary, measurement systems that connects business targets and capacities to business operations and market conditions.

While these performance measurement systems are mainly proposed to assist small and medium-sized enterprises in improving performance, most of them do not take the following important aspects into consideration:

1. The measurements that are utilized as a part of a performance measurement system ought to have the ability to capture the organizations' performance.
2. Performance measurement ought to reflect clear links with different levels of decision-making, such as strategic and operational decisions.
3. Performance measurement should reflect a satisfactory balance between financial and non-financial aspects.
4. The individual needs and preferences of different small and medium-sized enterprises must be considered.

According to Tangen (2004, p.736), "The various approaches have a clear academic foundation and are theoretically sound, but they hardly aid the practical understanding of specific measures at an operational level." Therefore, a new approach is required to develop a performance measurement model that allows for more visibility and the linkage of all key business processes, and performance measures—a model that considers all forms of limitations that exist in small enterprises and in the supply chain structures and operations of small businesses—a performance measurement model that is capable of translating qualitative information into quantitative decisions as well as measuring and capturing owners' decisions and actions and their influences on business processes and market success.

1.1 Motivation

- SMEs have surpluses of financial measures, but their measurement systems are not derived from strategy, are often unclear with complex or obsolete data, and tend to be historically focused with outdated measures.
- Decisions made in small enterprises are usually informal and subjective, which leads to incorrect actions and undesirable results.
- Performance measurement research that focuses on the specific needs of small sized enterprises has been in existence for decades; however, it appears that this research has not fully satisfied the needs of SMEs.
- Different multi-dimensional performance measurement models have been created to improve internal performance, but they overlook practical realizations and the

links among small business characteristics, structures, operations, and measurements at the operational level.

- A poor fit exists between supply chain management and SMEs. This is attributed to the improper implementation of supply chain management by SMEs and the lack of the use of supply chain management to complement strategic focus.

1.2 Thesis Statement

A well-defined performance measurement and improvement model, suitable for small-size enterprises that is capable of translating qualitative decisions into quantitative data, providing decision support, linking and evaluating decisions, and measuring performance has been formulated.

1.3 Research Objective

This research aimed at developing a comprehensive and flexible performance improvement and measurement model that has the ability to convert qualitative strategic information into quantitative, actionable decisions in order to help assess the performance of small and medium-sized enterprises. To accomplish this, the most appropriate performance measurement and improvement elements, attributes, and measures were identified, and the connections among them were considered. Performance measurement is connected to strategic decisions, and it allows management to support decision-makers in assessing the status of their small enterprise. The research can be divided into the following two research points:

- To develop a comprehensive and flexible model with which to assess and measure performance in small and medium-sized enterprises
- To develop a mathematical equation with which to calculate overall performance

1.4 Approach

In order to achieve the research objectives, the following approaches were used:

- A review of the related literature to investigate and identify the needs and characteristics of small and medium-sized enterprises (SMEs)
- The identification of gaps in performance measurement systems (PMS) and their implementation in SMEs
- The proposal of a performance measurement and improvement model based on SMEs limitations, PMS characteristics and the gaps among them
- The implementation of a multi-criteria decision analysis approach that assist in translating subjective decisions into objective decisions, and the selection and ranking of elements into one comprehensive business performance model
- The identification of an appropriate software-based simulation tool
- The testing and verification of the proposed model and the application of the model in a small manufacturing enterprise

CHAPTER 2

REVIEW OF LITERATURE

This chapter summarizes the literature related to small and medium-sized enterprises (SMEs). It starts with the classification of firms and categorization standards used in various economies and the difference between large firms and smaller ones. This chapter emphasizes the economic and social value that small enterprises contribute to nations. It also provides readers with sufficient information and background about the special characteristics of small enterprises, the surrounding hindrances, and the effects of both on the performance and survival of a small business. The chapter also discusses supply chain performance measurement in large firms and SMEs.

2.1 Taxonomy of Enterprises and Firms

The size of a business can be defined in many ways. It can be defined by its annual gross or net revenue, by the size of its assets or its workforce, or by the value of its shipments or annual sale. However, businesses are defined based on the needs or the requirements of institutions. Industry Canada uses definitions based on workforce size or the number of employees in a firm, which vary according to the industry. For example, goods-producers are considered small if they have less than 100 employees. If they have between 100 and 499 employees, then the firm is considered to be medium-sized (Industry Canada, 2013). In the United States, firms with more than 10 employees and less than 100 are considered small, while firms with 100 to 499 employees are considered medium-sized enterprises. In Germany and the U.K., firms with 49 or less employees are considered small, while those with 50 to 249 are classified as medium-sized enterprises. Table 1 shows the general classifications of SMEs in different countries.

Table 1

Taxonomy of Firms in Various Countries

	MSME Definitions (number of employees)		
Country Name	Micro	Small	Medium
U.S.A	1-9	10-99	100-499
Japan	1-4	5-19	20-299
France	1-9	10-49	50-249
Germany	1-9	10-49	50-249
Canada	1-4	5-99	100-499
Brazil	1-9	10-49	50-99
Australia	1-4	5-19	20-199
United Kingdom	1-9	10-49	50-249

Source: Worldbank.org

The term “small and medium-sized enterprises” frequently describes firms with less than 500 employees, while firms with 500 or more employees are classified as large firms. In Canada, for example, 98% of businesses are considered small and micro businesses (with less than 100 employees).

2.2 Characteristics of Large Firms and SMEs

There are certain characteristics that differentiate large companies from SMEs, such as culture and behavior, systems and procedures, structure, human resources, and market and customers (Deros et al., 2006). For example, the structures of SMEs are flat; there are limited layers of management, top management is greatly visible and near to the delivery point, they have smaller amount of delegation, the division of activities is narrow and uncertain, there is a lower degree of specialization, they have elastic structures, and information flows more freely. In regard to the structures of large firms, however, they involve many layers of management, top management is not visible and is far from the point of delivery, they have a lot of delegations with clear divisions of activates and a higher degree of specialization, they show rigid structures and information flows, and their strategic processes are done on wholesale levels (Deros et al., 2006).

The systems and procedures in SMEs consist of activities and operations that are not governed by formal rules and procedures; they use informal evaluation, incidences of ‘gut feeling’ decisions, simple planning and control systems, informal reporting procedures, and flexible and adaptable processes. In large firms, however, the systems and procedures include activities and operations that are governed by formal rules and procedures; they use a high degree of standardization, complicated planning and control systems, formal evaluation, control, and reporting procedures, rigid processes, and most decisions are made based on facts. Table 2 gives a summary of large company and SME characteristics. The literature on this topic underlines the fact that the central distinction between small and large firms is the greater external uncertainty of the environments in which small firms operate and the greater internal consistency of their motivations and actions (Bititci et al., 2005). Welsh and White (1981) suggested that a small company is not a little large business because there are many differences between them, such as structure, policy making, procedures, and the utilization of resources, to the extent that the application of large business concepts directly to SMEs may not be appropriate.

Table 2

Characteristics of SMES Versus Large Firms

	SMEs	Large Firms
Structure	• Flat with very few layers of management top management highly visible and closed to the point of delivery • Less delegation • Division of activates limited and unclear • Lower degree of specialization • Flexible structure and information flows • Strategic process incremental and heuristic	• Many layers of management levels top management not visible and far from the point of delivery • A lot of delegations • Clear division of activates • High degree of specialization • Rigid structure and information flow • Strategic process done wholesale
System & Procedure	• Activities and operations not governed by formal rules and procedures • Simple planning and control system • Incidences of "gut feeling" decisions • Informal evaluation, control, and reporting procedure • Flexible and adaptable processes	• Activities and operations governed by formal rules and procedures • High degree of standardization • Complicated planning and control system • Most decisions made based on facts • Formal evaluation, control, and reporting procedure & Rigid processes
Human Resource	• High personal authority and commitment of the owner • Few decision-makers • Dominated by pioneers and entrepreneurs • Individual creativity encourages and high incidence of innovativeness • Modest human capital financial resources and know-how • Low degree of resistance to changes • More generalists, some stuff may cover more than one department	• Many decision-makers • Encourages teams creativity • Abundant skilled human capital, financial • resources and know-how • Individuals could not see directly the results of their endeavors • High degree of resistance to changes • More specialists, dedicated only to one department
Markets & Customers	• Span of activates narrow • limited external contact • Normally dependent on small customers • Products and services mostly for local market , few national or international markets	• Large span of activities • Large external contacts • Normally dependent on large customer • Compete based on quality, price and delivery performance • Products and services for local and international markets

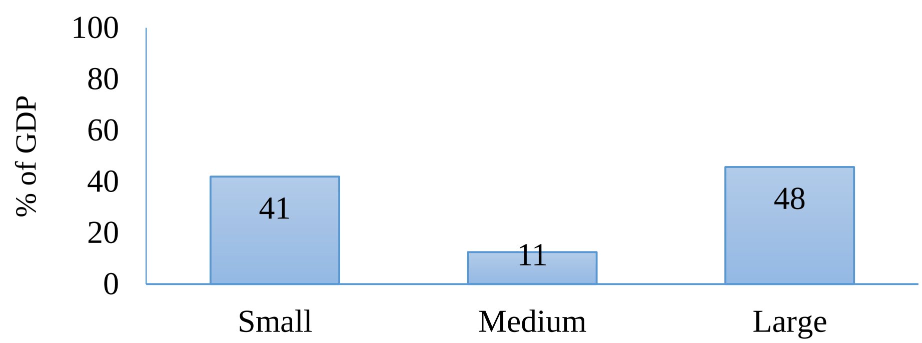
Source: Deros et al., 2006.

2.3 Importance of Small and Medium-Sized Enterprises

Small and medium-sized enterprises (SMEs) have received great attention in recent years due to the important role they play in most national economies, in both developed and developing countries. They are perceived as the main drivers of economic growth, product innovation, and job creation. They are often the suppliers of products and services to larger companies. Some advanced economies are successful because SMEs form a fundamental part of the economy.

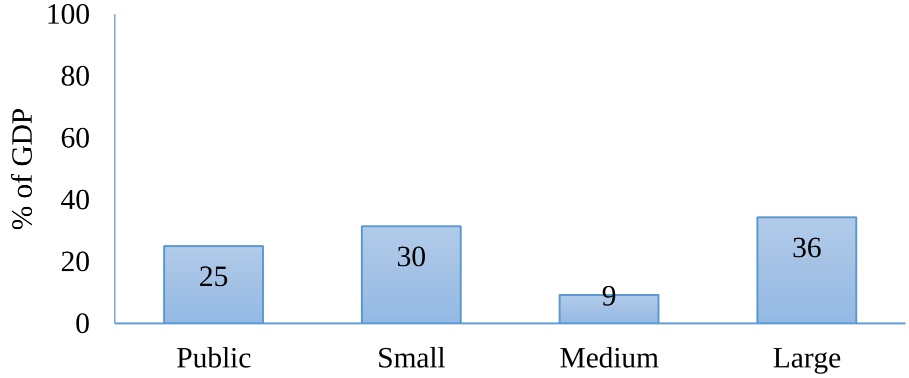
In a recent report, Statistics Canada found that small enterprises (those with 1 to 99 workers) represented around 41% of private segment GDP and SMEs with 1 to 499 workers represented around 52%. Considering both the private and public segments, small enterprises in the private division represent around 30% of the GDP, and medium-sized organizations represent 9%.

In the meantime, large firms account for 36% of the GDP, while the public sector accounts for only 25% (see *Figure 1* and *Figure 2*) (Industry Canada, 2013). Moreover, about 44% of manufacturing contributions to Canada's GDP come from SMEs, and the remaining 46% comes from large firms.



Source: Industry Canada, 2013.

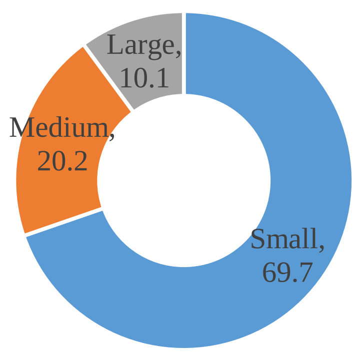
Figure 1. Contribution to Canada's GDP by firm size in private sector.



Source: Industry Canada, 2013.

Figure 2. Contribution to Canada's GDP by firm size (public and private).

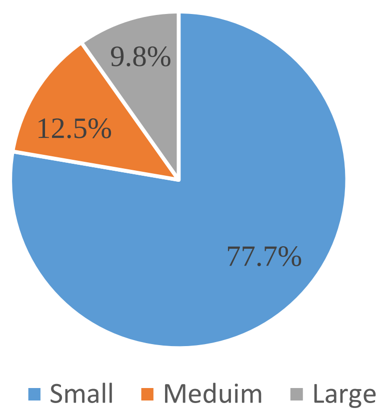
In the year of 2012, there were over 7.7 million employees, or 69.7% of the total private force work, worked for small businesses. (See *Figure 3*). Totally, around 10 million individuals workers in SMEs, or 89.9% of employees. In Canada, 98% of businesses have 1 to 99 employees (Industry Canada, 2013).



Source: Industry Canada, 2013.

Figure 3. Share in percentage of total private employment by size of business.

Small businesses produce a larger role in job market creation than larger firms. They generated 77.7% of all private jobs from 2002 to 2012 (see Figure 4). On average, small businesses create a little over 100,000 jobs each year. Medium-sized and large businesses account for 1.6% and 0.1% of all firms, respectively. They produced 12.5% and 9.8% of new jobs over the same years, respectively representing about 17,000 and 11,800 jobs each year on average (Industry Canada, 2013).



Source: Industry Canada, 2013.

Figure 4. Percentage of private job creation by size of business.

2.4 SMEs' Challenges and Obstacles

In recent years, literature has identified the increasing complexity of small and medium-sized enterprises (SMEs) and emphasised the challenges that most SMEs encounter. For example, Ndubisi (2006) highlighted many of the challenges that are still facing SMEs. He identified five key challenges: lack of access to finances, human resource constraints, the limited ability or inability to adopt technology, lack of information on potential markets and customers, and global competition. He also argued that there is a high risk that SMEs will be wiped out if they do not increase their competitiveness in the new, rapidly changing world of globalization (Ndubisi, 2006).

Silas Titus (2014) identified two types of challenges: managerial challenges and financial challenges. The managerial challenges include the following: lack of industry experience; poor business planning; fragile systems of control; management ineffectiveness; ignoring the competition; access to human capital, markets, and technology; and financial challenges, such as inadequate finance and lack of adequate cash flow (Titus, 2014). Some of these challenges are summarized below (Reasons, 2014).

2.4.1. Industry experience. Businesses work according to their own environment. Therefore, the internal resources and core competencies of a business must be linked to the needs of its environment. Lack of industry experience will lead to weak organization and the poor utilization of resources. Small firms have to pay attention to their industry's structure and carefully study and analyze changes because changes in the external environment can significantly influence a firm and its resources.

2.4.2. Business planning. A good business plan helps identify a business' mission, cost, structure, customers, markets, and other external influences. A good business plan also helps in identifying the strengths and weaknesses of a business. Around 90% of business failures in the United States are caused by a lack of general business management skills and planning.

2.4.3. Poor system of control. Metrics and measures help managers to manage organizational activities. If a firm cannot regulate the external influences that affect its environment, it can adjust its internal organizational activities. Therefore, a system of controls is required to measure the performance and achievements of a business. Controls can be implemented in several aspects of an SME, including controls for measuring the quality and quantity of decisions and processes. Therefore, a performance measurement system is an essential part of a control system through which a firm can measure decisions and operation outcomes against designed and planned business goals. Small firms usually do not have power to control most external factors, such as markets, supply, and competitors, but they can adjust their internal decisions, activities, and operations to meet any uncontrollable changes. A lack of proper control of internal activities can eventually lead to business failure. An effective system of control measures the quality of operations and outputs, financial aspects, and overall business performance.

2.4.4. Management incompetence. Effective management properly implements and monitors the strategic, tactical, and operational plans of a business. Around 90% of business failures are linked to management inadequacy.

2.4.5. Access to finance or inadequate financing. For many SMEs, although financial service suppliers are making funds available for business growth, the reality is that it is getting tougher to secure financing. The global financial crisis and markets collapse have caused financial institutions to be more careful, and credit treating has become so complex that, frequently, SMEs find it difficult to understand both the procedures and the decisions when it comes to loan processing.

2.4.6. Weakened customer base. Expanding the market is an important element in building a business. This means being flexible enough to adapt to new trends and concepts. Therefore, it is recommended for small enterprises to focus on a market strategy that generates profits and works well for its specific business type.

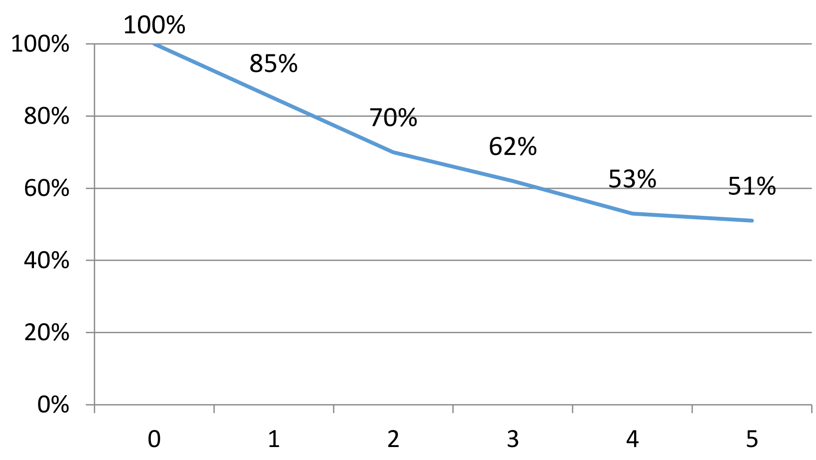
2.5 Challenges against Characteristics

Existing literature revealed that small and medium-sized enterprises are distinguished from larger firms by a number of key characteristics (Hudson, Lean & Smart, 2001). According to the researchers, SMEs are characterized by the following:

- Personalized administration frameworks with little designation
- Severe asset confinements (related to talented labour and finances)
- Flat and flexible structures
- Reactive management and 'fire-fighting' attitudes
- Casual strategies and subjective decision-making
- Dependencies on small numbers of customers (narrow markets)
- High innovativeness

These characteristics are also considered critical factors in influencing the implementation of continuous improvement processes as well as performance measurement systems in SMEs (Garengo, Biazzo & Bititci, 2005). For example, SMEs experience the significant effects cause by constrained assets for information examination processes needed for well-known performance measurement models. These characteristics are common in all SMEs; however, the actual impacts of them depend on firm size and the volume of the business and market (Alomar & Pasek, 2014). For example, a medium-sized manufacturing firm usually has a better position in terms of internal capabilities, technology, resources, number of customers, and market share. Such firms also have better management and more skilled employees than smaller enterprises (with less than100 employees).

According to Industry Canada (2013), the survival of businesses reflects their productivity, innovation, and resourcefulness, as well as their adaptability to changing market conditions. Figure 5 shows survival rates for Canadian SMEs with less than 250 workers. The rates represent the percentage of firms that survived until 2006 and were formed one to five years prior to that. According to Industry Canada (2013), "About 85% of businesses that entered the market in 2005 survived for one full year; however survival rates declined over time. About 70% of firms survived for two years, 62% survived for three years, and only 51% of firms survived for five years. The fact that half of the new businesses survived their first five years of operation suggests that these businesses are able to attain competitive advantages in their markets."



Source: Industry Canada, 2013

Figure 5. Survival rates of Canadian employer businesses (with fewer than 250 employees), 2001–2006.

In terms of strategy, SMEs often either do not consider long-term strategies or treat them in an ambiguous manner (Taticchi, 2008). SMEs are often characterized by weak strategic planning, and their decision-making processes are not formalized (Bititci, et al., 2002). Although scholars and practitioners have encouraged small enterprises to use formal strategic management modes to leverage their performance, small enterprises continue to depict informal strategic management modes, characterized by unstructured decision-making processes.

The nonattendance of clear systems and methodologies to bolster the control process indorses both a short-term orientation and planning and a reactive approach to managing the business activities (Garengo et al., 2005). This represents a crafting issue in PMM as PMSs ordinarily use well-defined strategy. The dynamic strategies of small businesses mean that they change their decisions more frequently than larger firms. This significantly impacts inward operations and the relations with clients and suppliers. Such conduct, the use of a dynamic strategy, requires a superior arrangement of control with better capacities to quickly and adequately control the outcomes on the inward and outer operations of the business.

These constraints and limitations in small manufacturing enterprises stress the significance of executing performance measurement and control systems. Such a system must efficiently and effectively reflect key business processes with fewer, but more critical, measures (when compared to the systems used in larger firms) that are composed in a reasonable structure and customized to fit the particular needs of every individual enterprise (Hudson et al., 2001).

2.6 Definition and Importance of Performance Measurement

Performance measurement has become an essential subject for academics and practitioners since the beginning of the 1990s (Gosselin, 2005). Neely and others (2005) defined *performance measurement* as “the process of quantifying action in which measurement is the process of quantification and action leads to performance." They further proposed that performance is a function of the efficiency and the effectiveness of actions undertaken (Neely, et al, 2005).

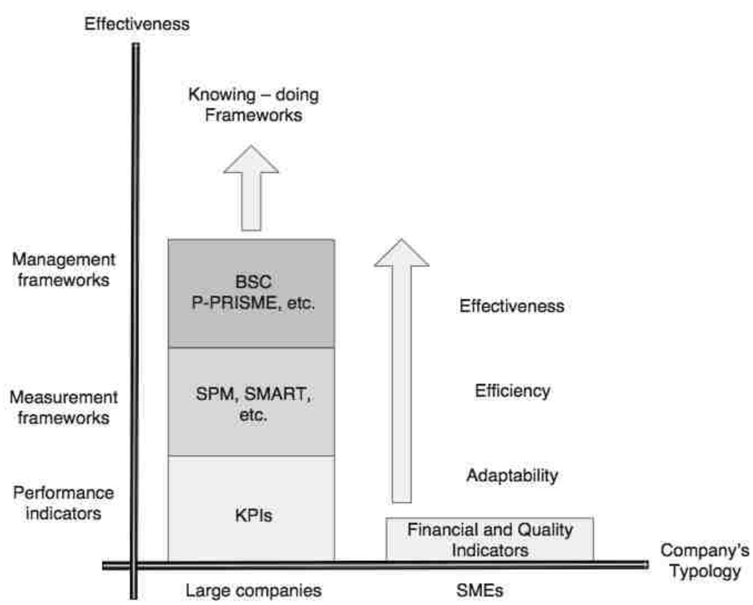
- Performance measurement is the process of quantifying the efficiency and effectiveness of actions.
- A performance measure is a metric used to quantify the efficiency and/or effectiveness of an action.
- A performance measurement system is the set of metrics used to quantify both the efficiency and effectiveness of actions.

Based on the performance measurement literature, there are two categories of effectiveness and efficiency that are commonly addressed as the main indicators of a business' performance. Effectiveness states the degree to which clients' needs are met, while efficiency is a measure of how firms utilize their resources. Thus, the level of performance a business achieves is a component of the productivity and adequacy of the activities it attempts (Neely et al., 2005).Businesses achieve goals by satisfying customers with better efficiency and effectiveness than rivals (Kotler, 2000). As cited in Mola (2004), performance measurement is the process of creating indicators that report on the accomplishments and improvement of an organization. Najmi and Kehoe (2001) assumed that performance measures are built up to accomplish objectives and are delivered with a plan to direct, and enhance business' functions. Typically, performance measurement is used in the context of guiding organizational change and development (Mola, 2004). Ittner and Larcker (2003) suggested that performance measurement is used to help direct the allocation of resources, assess and communicate progress towards strategic objectives, and evaluate managerial performance. Neely and others (1994) claimed that performance measurement aids managers in identifying healthy performance, makes the trade-offs among profits and investments clear, provides a means of introducing individual strategic goals and a method for presenting individual key targets. Performance measurement is thought to be the center of control and management systems. It assumes a vital part in creating key strategic plans, evaluating organizational goals, and motivating organizational learning. Likewise, it assumes an important part in assessing businesses gains, sustaining competitive advantages, and directing corrective adjustments, activities, and actions (Holban, 2009). Various researchers have linked the success of businesses to the type of performance measurement system they use and to the successful design and implementation of the measurement systems used (Alomar & Pasek, 2014).

Other researchers have considered strategic performance measurement systems as means to attain competitive advantages and continuous improvement, as well as methods for responding to internal and external changes (Cocca & Alberti, 2009). Therefore, the performance measurement systems' (PMSs) are the tools that support decision-making for executing or selecting improvement actions or forming objectives (Bititci, 1997; Neely, 2000). Consequently, a performance measurement system is a multi-criteria instrument that is made of a group of performance expressions, which are also referred to as *metrics* (Melnyk et al., 2004).

2.7 Performance Measurement Systems

An extensive survey was conducted by Taticchi et al. (2010) to review the existing literature. It covered over 6,600 journal articles on performance measurement and management systems over a publication period of forty years. It was observed that interest in performance measurement and management subjects increased over the last two decades. The evolution of the focus on performance from a financial viewpoint shifted towards focusing on performance from non-financial perspectives. However, based on previous studies, it is understood that there was a significant lack of work in measuring and assessing the performance of SMEs (Taticchi et al., 2010). A similar statement was published more than ten years ago by Hudson (2001), which stated that, regardless of the broad research that has been done to examine the needs and qualities of PMSs in large organizations, there is a remarkable absence of published research within the context of small and medium-sized enterprises (see Figure 6). Taticchi and others categorized the previous works into three types of research as shown in table 3 (Taticchi et al., 2010). Some of the well-known performance measurement frameworks and models will be presented with pros and cons as well.



Source: Taticchi et al., 2010.

Figure 6. Large companies and SMEs: Future areas of research.

Table 3

Basic Analysis of the Previous Works on PMMS

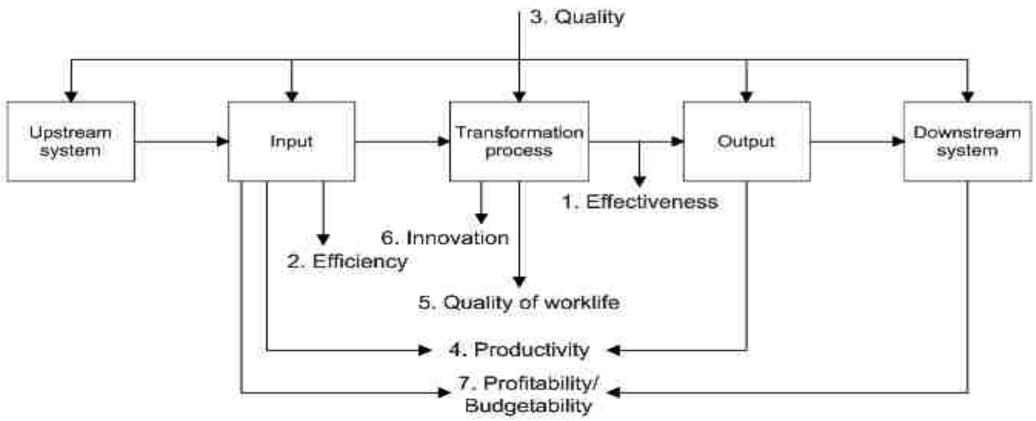
Year	Integrated frameworks for PMM	Year	Models to face specific issues in PMM	Year	Other relevant models for PMM system design
1988	The Strategic Measurement Analysis and Reporting Technique	1980	The Economic Value Added Model	1988	The Activity-based Costing
1989	The Supportive Performance Measures	1990	The Performance Measurement Questionnaire	1990	The Customer Value Analysis
1991	The Results and Determinants Framework	1995	The Return on Quality	1999	The European Foundation for Quality Management Model
1992	The Balanced Scorecard	1996	The Cambridge Performance Measurement Framework	2001	The Manufacturing System Design Decomposition
1994	The Service Profit Chain	1996	The Consistent Performance Measurement System		
1997	The Integrated Performance Measurement System	2001	The Action Profit Linkage Model.		
1998	The Comparative Business Scorecard	2004	The Performance Planning Value Chain		
1998	The Integrated Performance Measurement Framework	2004	The Capability Economic Value of Intangible and Tangible Assets Model		
2000	The Dynamic Performance Measurement System	2006	The Performance, Development and Growth Benchmarking System		
2001	The Performance Prism	2007	The Unused Capacity Decomposition Framework		

Source: Taticchi et al., 2010.

2.7.1. Activity-based costing. Activity-based costing (ABC) was created in the late of 1980s by Johnson and Kaplan as a push to determine some of the essential insufficiencies of traditional cost accounting. The ABC methodology is concerned with the expense of business tasks and activities and their connections with the makers of particular merchandise (Hill, 1995). Basically, the ABC method aims to investigate and examine the indirect costs within a company and to understand the activities that cause these costs. These types of activities are called *cost drivers*, and they can be used to allocate overheads to particular products. It is supposed that ABC results in a more accurate identification of costs than traditional cost allocation.

The ABC can be of pragmatic worth for item valuing, production decision-making, reducing overhead costs, and persistent change and improvement. In any case, there are analysts who claim that the contention that ABC provides more exact item expenses has never been demonstrated (Tangen, 2004). Moreover, activity-based costing depends heavily on the assumption of proportional activity cost structures, and it ignores resource and technological constraints (Yahya Zadeh, 2011).

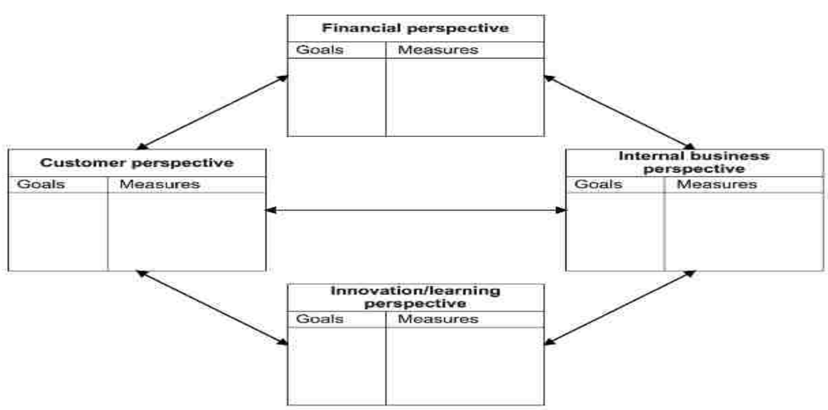
2.7.2. Sink and Tuttle model. This model claims that business performance is an unpredictable interrelationship between seven execution criteria (Sink and Tuttle, 1989), (see Figure 7). Albeit impressive changes in industry settings and conditions have happened since this model was initially exhibited, these seven performance criteria are still imperative. On the other hand, this model has a few impediments. For instance, it does not consider the requirement for adaptability (Tangen, 2004). Moreover, this type of model requires thorough and accurate analysis that can be time consuming, and it requires expert advice to implement.



Source: Sink and Tuttle, 1989.

Figure 7. Sink and Tuttle performance measurement model.

2.7.3. Balanced scorecard (BSC). Created and advanced by Kaplan and Norton (1992). The BSC is a framework that can be utilized to convert an organization's mission and strategic goals into an arrangement of performance measures. The balance scorecard proposes that an organization ought to utilize a balanced measures that allows top management to have exhaustive evidence of an organization's performance based on imperative perspectives that give answers to four essential inquiries (Figure 8).



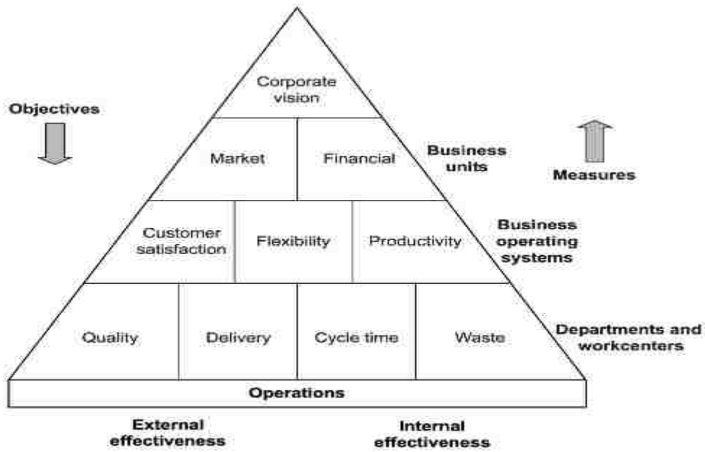
Source: Kaplan and Norton, 1992.

Figure 8. Balance Scorecard by Kaplan and Norton, 1992.

The balanced scorecard incorporates budgetary and non-money related performance measures. By giving data from four perspectives, the balanced scorecard decreases data over-burden by controlling the quantity of measures utilized. Likewise, it pushes administrators to concentrate on the measures that are generally significant. The BSC is designed to provide top management with an overall view of performance. Thus, it is not intended for, nor is it applicable to, the factory operations level. The balanced scorecard is constructed as a monitoring and controlling tool rather than an improvement tool (Tangen, 2004).

Moreover, it gives little direction on how the proper measures can be distinguished, presented, or used to deal with a business. Furthermore, top-level administration decision support measures may not be the most appropriate method to bolster lower-level operations.

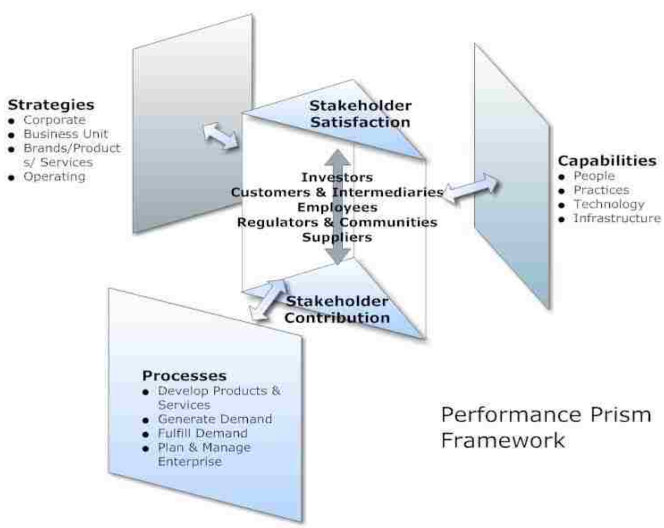
2.7.4. The performance pyramid. Proposed by Cross and Lynch (1992) (see Figure 9). The attractiveness of this framework is that it links business strategy with day-to-day operations. The performance pyramid connects strategy with operations by interpreting targets starting from the top (taking into account client needs) and measures from the base up. It incorporates four levels of targets that address an organization's outside effectiveness (left half of the pyramid) and its inner efficiency (right half of the pyramid). The key strength of the performance pyramid is its effort to integrate business objectives with operational performance indicators. Nevertheless, it does not offer any mechanism with which to identify key performance indicators, nor does it clearly integrate the concept of continuous improvement (Tangen, 2004). Moreover, it does not include manufacturing processes or business activities.



Source: Cross and Lynch, 1991.

Figure 9. Performance pyramid proposed by Cross and Lynch.

2.7.5. The performance prism. One of the recently developed conceptual frameworks is the performance prism (Figure 10). It suggests that a performance measurement system must be planned around five distinctive, however, linked standpoints of performance (Neely et al., 2001). The five dimensions are: stakeholder satisfaction; strategies; processes; capabilities; and stakeholder's contributions

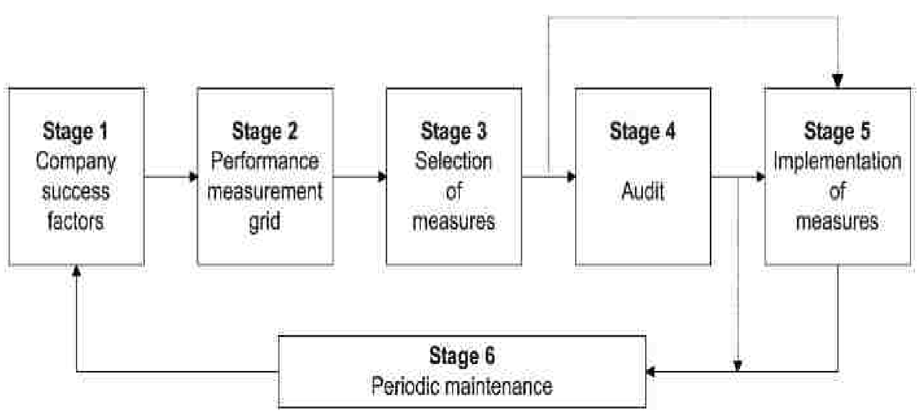


Source: Smartdraw.com, 2015.

Figure 10. Performance prism.

The performance prism starts its process by thinking about the stakeholders and what they want. The performance prism has a more wide perspective of partners than other performance measurement frameworks and models (Neely et al., 2001). The strong point of this work is that it addresses the issues in the present strategy before the procedure of selecting measures is begun. This step ensures that the performance measures have a strong groundwork. However, the performance prism offers minimal help about how the performance measures will be realized, and little thought is given to the current PMSs that organizations may already be using (Tangen, 2004).

2.7.6. Medori and Steeple's framework. In 2000, Medori and Steeple presented an integrated framework for auditing and enhancing performance measurement systems. It consists of six detailed stages (see Figure 11). The framework begins with defining a company's strategy and success factors. The remaining steps and stages are: matching strategy to predefined competitive priorities; selection of appropriate measures, auditing existing PMS and measures. The actual implementation of the measures comes in stage 5, and the periodic review of the firms' performance measurement system starts in stage 6.



Source: Medori and Steeple, 2000.

Figure 11. Medori and Steeple's framework.

As opposed to numerous different systems, this one goes past straightforward rules. A noteworthy favorable aspect of this framework is that it can be utilized to outline a new PMS or to upgrade a current PMS. It additionally contains a special depiction of how performance measures ought to be figured out. Its limits are mostly situated in stage 2, where a performance measurement framework is made with a specific end goal to give the PMS its fundamental configuration. Little direction is given here, and the network is just built from six focused needs (Tangen, 2004; Kurien and Qureshi, 2011).

2.7.7. Theory of constraints. In 1990, Goldratt developed an approach called the theory of constraints (TOC). A constraint is characterized as anything that restricts the system from accomplishing higher performance in respect to its motivation. The TOC offers an efficient and focused process that organizations utilize to seek effective change. The TOC's "five steps of focusing" are conducted in the following way (Goldratt, 1990).

1. Identify the system's constraints.
2. Decide how to exploit systems constraints.
3. Subordinate everything else to the above decisions.
4. Elevate the system's constraints.
5. When a constraint is broken, go back to step 1.

The TOC approach provides focus in a world of information overload. In addition, the performance measures within the TOC are easy to access and easy to understand. However, the TOC is far from being a comprehensive performance measurement system (Tangen, 2004).

Some researchers point out that, even if general models were applied correctly, they would be inadequate for the particular characteristics of SMEs because "the small enterprise is different from the big company; you cannot simply look at the needs of SMEs by turning your binoculars upside down and making small what was big"(Biazzo, et al., 2012). Other researchers who have evaluated the practical implementation of the well-known performance measurement such as, for example, balanced scorecard in SMEs conclude that this model is not suitable for SMEs (Hvolby & Thorstenson, 2000; McAdam, 2000).

2.8 Performance Measurement System for SMEs

The literature on PMSs for SMEs compared to the literature about PMSs for large enterprises is immature. For example, the first PMS models for large companies were developed in the 1980s, while the first literature related to the PMSs of small and medium-sized enterprise appeared in the latter half of the 1990s (Taticchi et al., 2010). During this period, SMEs basically used financial performance measures designed for large companies, such as ROI, ROE, ROCE, and their derivatives (Taticchi et al., 2010).

According to Taticchi and others, the exploration of performance measurement in connection to SMEs took two headings; the first was the application and adjustment of the models produced for large firms and the second was the advancement of particular models for SMEs. Within the first, it is conceivable to discover instances of the usage of well-known models like the balance scorecard and utilizations of the ABC. In the literature, it is also possible to find, three frameworks proposing integrated approaches to performance measurement (Garengo et al., 2005; Taticchi et al., 2010). Table 4 shows the classifications of the models/research studies related to SMEs. Although focused approaches, such as cost accounting approaches, can be helpful in measuring certain dimensions (i.e., the total cost structure and calculation), which in turn, helps enterprises properly set product prices, profits, and overhead cost reduction, researchers claim that these financial models do not cover other manufacturing aspects that are relevant to a firm's competitive strategy and customer satisfaction (Tangen, 2004). However, despite the remarkable progress and evolution of performance measurement models and frameworks, many businesses, especially small ones, are still mainly depending on traditional financial performance measures.

Financial performance measurement systems have many disadvantages and weaknesses that affect the long term ability of an enterprise to compete in the marketplace. Some of these weaknesses are the following (Tangen, 2004):

- Measuring cost, cost efficiency, and utilization leads to short term thinking to reducing costs at the expense of long term planning and improvement.
- Financial measures usually provide businesses with obsolete information, showing only the results of previous actions.
- Financial measures usually focus on the return on investment (ROI) and are rarely directed to manufacturing strategies.

In opposition to these financial performance measurement systems, there are multi-dimensional models, such as the organizational performance measurement (OPM) system, the dynamic integrated performance measurement (DIPM) system, and the balance scorecard (BSC) system, which involve different dimensions in terms of financial and non-financial measures. However, these systems have certain weaknesses that create some difficulties in the implementation process, mainly in small businesses.

Table 4

Basic Analysis of Major Works Conducted for SMEs

Year	**Integrated frameworks for SME PMM**	**Year**	**Application/adaptation of large companies PMM models**	Year	**Models to face specific issues in SME**
2000	OPM: a system for organizational performance measurement	1995	Model for quality-based performances	1998	Customer orientation and performance
2001	Effective performance measurement in SMEs	1997	BSC application to SMEs	2000	Computer-based performance measurement in SMEs
2002	Dynamic integrated performance measurement system	1999	Activity based costing in SMEs	2007	A BPI framework and PAM for SMEs
Year	**Interesting researches for PMM system design in SMEs**	2000	Quality models in an SME context		
2000	Performance measurement based on SME owner's objectives	2000	Performance measurements in the implementation of CIM in SMEs		
2001	Indicators for performance measurement in SMEs	2004	A strategic planning model for SMEs based on the BSC		
2001	Theory and practice in SME performance measurement systems	2007	BSC implementation in a not-for-profit SME		
2005	Practice of performance measurement				
2008	A performance measurement model based on the grounded theory approach.				

Source: Taticchi et al., 2010.

For example, the BSC is mainly designed to provide senior managers with a general view of performance improvement but not of the factory operations level, in addition, it provides little guidance on how the correct measures can be identified, presented, and used in order to improve business operations. (Ghalayini et al., 1997). One of the main weaknesses with the application of multi-dimensional performance measurement systems in small enterprises is that their structures are not unmistakably organized and, hence, application is subjective. Table 5 shows the strengths and weaknesses of some models that are fundamentally designed to assist small and medium-sized enterprises in improving performance. As Tangen (2004) explains, “These various approaches have a clear academic foundation and are theoretically sound, but they hardly aid the practical understanding of specific measures at an operational level.” This is considered a major obstacle in implementing multi-dimensional performance measurement systems in small enterprises. On the other hand, many small enterprises are family-owned businesses and can often be characterized by a shortage of financial resources. They do not have the assets to possess advanced technology, bringing about low efficiency, an inability to take after the best practices, an inability to accumulate adequate pertinent information for analysis, and they confront constraints on their operations (Taticchi et al., 2010). In 2001, Hudson and others conducted an empirical study on the implementation of performance measurement systems in small and medium-sized enterprises. The researchers found that all companies in the study had a surplus of financial measures, but their measurement systems were not derived from strategy, vague, with out of date information, and with some obsolete measures (Hudson et al., 2001).

Table 5

Strengths and Weaknesses of Some Models that are Fundamentally Designed to Assist Small and Medium-Sized Enterprises

Model	Author and Year	Strengths	Weaknesses
Customer Orientation and Performance	Appiah-Adu, Singh, 1998	Focuses on the effects of customer orientation on performance measures. It has been validated on a large number of UK firms	The model focuses only on market perspective. It does not permit holistic view of performance
Organizational Performance Measurement (OPM)	Chennel et al., 2000	The system has been developed from an empirical case study research in large firms and SMEs	Objectives are not clearly defined. The system proposed is in the dissemination phase and it has to be tested yet
Quality Models in an SME Context	McAadm, 2000	The model has increased the measurements and links between strategy and operational process.	The model uses BSC as quality model. The model permits only qualitative analysis
Improving Control Through Effective PM in SMEs	Hudson et al., 2001	Developed for SMEs. Incremental and iterative process to measure performance Simple clear and well defined to implement, it has been applied in a study.	The model has been tested only in one company. It has to be proved the effective of flexibility and adaptability of the model.

Source: Taticchi et al., 2008.

An empirical survey conducted on eighty-three Danish enterprises found that 50% of them had either only one performance indicator, such as cost, or no performance indicator in place at all (Hvolby and Thorstenson, 2001). Another empirical study, conducted by Gosselin (2005), revealed that small and medium sized Canadian manufacturing firms continue to use financial measures. Despite the suggestions from specialists and scholastics, the extent of firms that execute well-known measuring frameworks, for example, the balance scorecard, is low (Gosselin, 2005). Also, the outcomes demonstrated that the sorts of performance measures utilized by firms were infrequently linked to strategy. The study likewise uncovered that around 70% of the organizations unsuccessfully implemented well-known strategic performance measurement models, such as BSC (Gosselin, 2005). Some researchers attributed the failure of implementing existing performance measurement systems in small and medium-sized enterprises to the following points:

- Most small and medium-sized enterprises use performance measurement models incorrectly (Tenhunen et al., 2001).
- The approaches of small and medium-sized enterprises to performance measurment are informal and not planned (Chennell et al., 2000).

2.9 Previous Research in Performance Dimensions and Measures

There are many financial and non-financial measures that can be used by enterprises. A summary of studies related to manufacturing performance dimensions is presented in Table 6 below.

Table 6

A Summary of Studies Related to Manufacturing Performance Dimensions

Author	Year	Performance Dimensions
Mapes et al.	2000	Customer Satisfaction, Quality, Delivery, Time
Najmi & Kehoe	2001	Finance, Time, Quality
Hudson et al.	2001	Time, Finance, Quality, Customer Satisfaction, Labour
Toni & Tonchia	2001	Quality, Delivery, Flexibility, Time, Cost
Christiansen et al.	2003	Quality, Cost, Delivery
Fynes et al.	2005	Cost, Quality, Delivery, Flexibility
Neely et al.	2005	Cost, Quality, Time, Flexibility
Meybodi	2006	Quality, Delivery, Labour, Cost
Liao & Qiang Tu	2008	Innovation, Cost, Flexibility, Quality Delivery

The table shows gaps in the studies in the selection of measures for small manufacturing enterprises. Although there are some differences in the selection of the dimensions from one study to another, quality was considered as a major aspect to measure among all of them. The majority of the studies also selected delivery, cost, and time as important performance dimensions. Figure 12 shows, in percentage, the use of different dimensions in the selected studies. For example, it shows that about 55% of the studies considered time as a critical dimension, 20% of the studies considered customer satisfaction as an important factor to measure, and only one study considered innovation as a critical dimension for a measuring system. Although these studies specified some of the major dimensions that most small and medium-sized manufacturing enterprises need to emphasize, they did show inconsistency in selecting these measures, which presents another challenge that small enterprises face. Moreover, each of the previously mentioned dimensions can be measured in many different ways. Table 7 below gives an idea about each of these dimensions and some of the related indicators that can be used to measure each one.

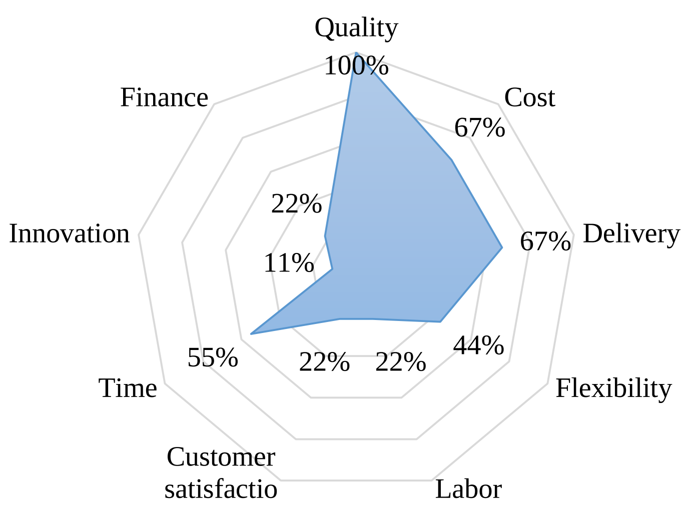


Figure 12. The use of different dimensions in the selected studies.

According to previous studies, a majority of SMEs depend on traditional management accounting systems when making strategic decisions. Nevertheless, “the traditional management accounting systems and financial measures simply do not provide the richness of information necessary to allow a company to remain competitive in today’s markets” (Najmi and Kehoe as cited Dixon, 2001, p.162). Monetary measures only show where the business has been, not where it is standing now and where it is heading.

Table 7

Performance Dimensions and Some of the Related Indicators

Quality	Time	Flexibility	Finance	Customer satisfaction	Human resources
Product performance	Lead time	Manufacturing effectiveness	Cash flow	Market share	Employee relationships
Delivery reliability	Delivery reliability	Resource utilisation	Market share	Service	Employee involvement
Waste	Process throughput time	Volume flexibility	Overhead cost reduction	Image	Workforce
Dependability	Process time	New product introduction	Inventory performance	Integration with customers	Employee skills
Innovation	Productivity	Computer systems	Cost control	Competitiveness	Learning
	Cycle time	Future growth	Sales	Innovation	Labour efficiency
	Delivery speed	Product innovation	Profitability	Delivery reliability	Quality of work life
	Labour efficiency		Efficiency		Resource utilisation
	Resource utilisation		Product cost reduction		Productivity

Source: Hudson et al., 2001.

2.10 Supply Chain Management

In today's business world, supply chain management is a key vital element for expanding viability and accomplishing intensity over rivals. If a supply chain can consistently provide the right product, at the right price, at the right time, and to the right customers, then it is highly likely that the supply chain can achieve and maintain a competitive advantage in the marketplace (Christopher & Towill, 2002). The term supply chain has been utilized to clarify the logistics, activities, and in planning of materials and information streams inside of an organization or remotely between organizations (Chen & Paulraj, 2004).

Supply chain management, as defined by Christopher (2011), is the management of downstream and upstream connections with suppliers and clients with the goal of providing greater customer value at less cost to the supply chain as a whole. In general, the growth of supply chain management is credited to several reasons, such as increasing globalization, lower hindrances to global trades, and changing in data accessibility and trade (Thakkar et al., 2009). The greatest contribution that the concept *supply chain management* has made is to inspire managers to think outside the organizational boundaries, to identify and understand the interdependencies that exist among and within firms and parties, and to recognize the effects of external factors in internal operations (Morgan, 2004).

2.10.1. Supply chain management in large firms and SMEs. Supply chain drivers, such as facilities, information, pricing, inventories, and transportation, play tremendous roles in terms of defining enterprise performance and its improvement potential (i.e., reducing cost, improving responsiveness, and flexibility), maintaining competitive strategies, and reducing uncertainties in markets. The impact and the applications of these drivers vary from one company to another. For example, large companies locate their manufacturing and storage facilities close to customers in order to increase responsiveness, while small enterprises are very limited with only one manufacturing facility in a very limited market. In large companies, manufacturing facilities are usually characterised by use of advanced technologies which makes their manufacturing processes more efficient and flexible to the changes in market demands, while small enterprises are very limited in terms of both technology and flexibility. Facility performance is usually measured by capacity, production cost per unit, utilization, flow time efficiency, product variety, etc.

Information also plays a huge role in improving supply chain performance. The right information at the right time can help improve the utilization, efficiency, and responsiveness of the manufacturer. Large companies usually share supply and demand figures with their suppliers, wholesalers, and retailers, which improves manufacturing and helps with accurately forecasting supply and demand. Limitations related to data, information technology and management, and the single facility locations of small manufacturing enterprises cause significant challenges that require tighter control of internal processes. Studies have revealed that the link between supply chain management and SMEs appears fragile and is associated with variety of barriers. A study on supply chain management within the context of small and medium-sized enterprises (Arend & Wisner, 2004) revealed the following:

- Small and medium-sized enterprises do not emphasize strategic focus areas, such as quality and product development to engage in supply chain management.

- Small and medium-sized enterprises received fewer benefits from supply chain partnerships.
- Small and medium-sized enterprises do not implement supply chain management as persistently as large firms.
- Small and medium-sized enterprises engage in short-sighted partner selection rather than more long term supply chain management relationships.

The following table summarizes the differences and strategic comparisons of large firms and small and medium-sized enterprises within the context of supply chain management.

Table 8

Strategic Comparison of Large Firms and SMEs

Category	SCM by large firms	SCM by SMEs
Competitive priority	Market dominance through sustaining large market share	Market niches through sustaining profitable market position
Key strategies	Exert influences in supply chain both upstream and downstream; strategic alliances with suppliers and distributors	Focus on specialized market; build on unique competencies; effective customers/suppliers management
External control structure	Command and control toward their small suppliers and distributors	Accept command and control by either OEM or 1st tier suppliers
Internal control structure	Decentralized, structured and highly specialized; multiple core competencies development	Centralized, semi-structured and moderately specialized; specific core competencies development
Goal of SCM	Operational effectiveness with multiple performance outcome requirements	Operational effectiveness with selective performance outcome requirements

Source: Hong et al., 2006

2.10.2. Supply chain performance management (SCPM). The supply chain performance measurement (SCPM) system progressed over two phases. The first was started in the late 1880s, whereas the second phase began in the late 1980s (Gomes et al., 2004). The primary stage was characterized by its cost accounting introduction. However, by the 1980s, traditional accounting measures were being analysed as inappropriate for overseeing the organizations of the day. The mid-1980s was a rotating point in performance measurement on the grounds that it denoted the start of the second period of the SCPM systems (Bourne et al., 2003). This stage was connected to the development of worldwide business practices. In the late 1980s, a few frameworks, which endeavored to present a more extensive perspective of performance measurement, began to show up (Gomes et al., 2004). Table 9 summarizes the evolution of SCPM in an organizational context. Although various theories and practices have been put in place through past papers, there is very little literature available (Thakkar et al., 2009).

Studies also indicate that some of the best practices suggested as instruments for improving supply chain performance may not have that significance (Lockamy et al., 2004). According to Beamon (1999), a supply chain measurement system has to emphasize three separate kinds of performance measures: resource measures that focus on cost factors, output measures that consider customer responsiveness, and flexibility measures that emphasize the ability to respond to a changing environment.

Table 9

The Evolution of Supply Chain Performance Models in an Orgnaizational Context

Period	Characteristics of Business Operations	Characteristics of PMS
Before 1980	Systematic large org.	• Cost accounting orientation. • Retroactive approach & results used to promote organizational efficiency. • PM dominated by transaction costs & profit determination.
1980-1990	Businesses became global	• Cost accounting orientation. • Retroactive approach & results used to promote organizational efficiency. • Enhanced to include operations and value added perspectives
1990-2000	Automation of business process	• A mixed of financial & non-financial orientation • A mixed of retroactive & proactive approach • Results are used to manage the entire org. • PMS enhanced to include quality, process, & customer focus
2000-2010	e-commerce & borderless business activities	• A balanced and integrated orientation • A more proactive approach • Results are used to enhance business responsiveness • PMS enhanced to give a balanced view of the business and included supply chain and inter-process activities.

Source: Kurien and Qureshi, 2011.

CHAPTER 3

METHODOLOGY AND THE MODEL

A performance measurement system can be seen as a multi-criteria instrument made of a group of performance expressions or measures (Melnyk, 2004). Therefore, conducting a multi-dimensional performance analysis involves solving a multi-criteria decision-making problem. MCDM or MCDA help in organizing and simplifying multi-criteria decision problems, which allows decision-makers to view problems in an understandable structure. The MCDA approach is designed for situations in which subjective decisions affect the decision-making process and by which the decisions are calculated to provide a numeric scale for ranking the nodes and alternatives

In this chapter, a conceptual model that takes into account some of the directions of previous related frameworks. The purpose is to build levels of internal and external factors required to assist in measuring and improving small enterprise performance. The conceptual model is expressed in a hierarchal structure that includes levels and criteria. These levels and criteria were connected to each other. The final models are expressed using a chosen MCDA analytical approach. Finally, this chapter will involve the verification, implementation, and assessment of different scenarios and their influences on the model outputs. Throughout the building and implementation processes of the models, we are going to answer questions such as: How can small manufacturing enterprises select the right dimensions or the right set of dimensions? Which processes are the most important? Can we link processes with performance measures, and how can this be done? What would be the indicators or measures for each dimension? What would the cost and benefit be for collecting and analyzing the selected dimensions? How can small enterprises convert and link their informal strategic decisions to strategic attributes and measures?

3.1 The Conceptual Model

The proposed methodology relies on the major aspects of the limitations of SME, process modeling, and PMS characteristics, as cited in the literature (see Figure 13). For instance, the business modeling pillar calls for process mapping and value chain, and it identifies the limits of activities both within and outside of business borders. The SME pillars represent the major aspects and limitations that are found in the literature and provide the right directions for connecting businesses with the other pillars. The PMS pillars provide strategic performance measurement guidelines and the overall structure of the model.

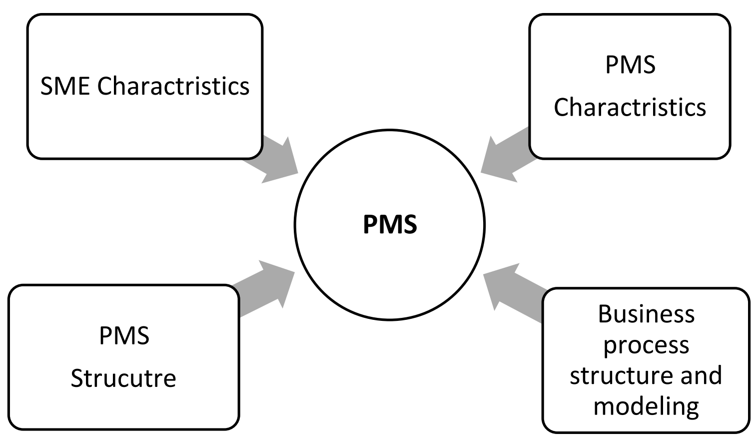


Figure 13. Pillars of the proposed model.

A well-designed performance measurement system is an analytical tool that provides the right information to the right people at the right time. It enables business owners and managers to make the right decisions. From this standpoint, the measurement system should follow the principles of closed-loop and feedback systems. In a feedback system, a closed-loop controller (decision maker) uses feedback to monitor and control the outputs of a system. Process inputs (managerial decisions) have an effect on the process outputs (cost, quality, speed, time, etc.), which is measured with metrics and processed by the controller; the result (the analyzed metrics) is fed back as an input to the decision-making process and the entire system, which closes the loop and provides a signal for a new loop; see Figure 14 below. Based on that, a conceptual performance measurement model, as shown in Figure 15, was developed.

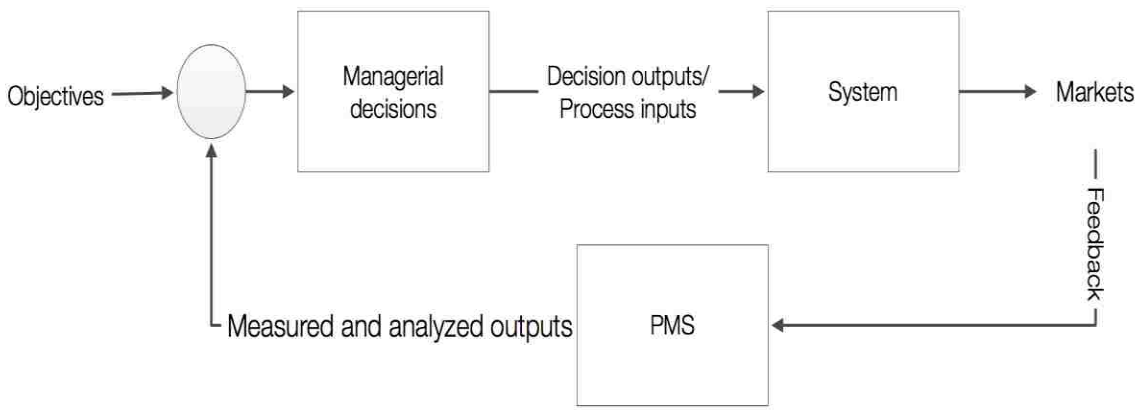


Figure 14. Closed loop performance measurement feedback system.

Figure 15 demonstrates and links different factors and levels within a feedback system that begins with decision-making and strategy formulation and moves through operations, tasks, and activities. The proposed model links the influential factors (i.e., demand) with strategic directions and success drivers (capabilities and resources) and measures. The levels have been identified and grouped into the following major levels:

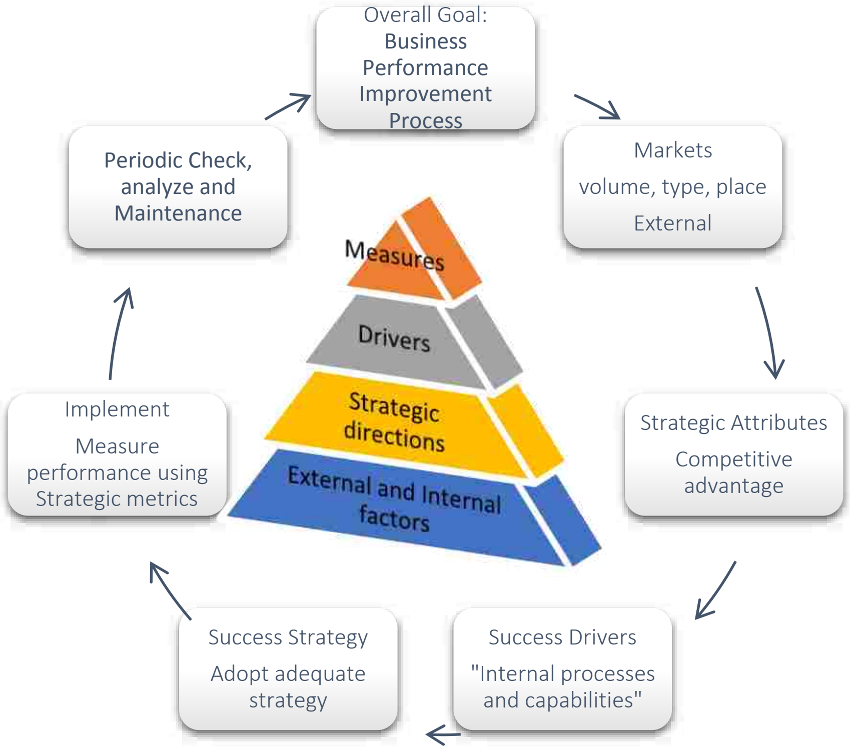


Figure 15. Conceptual model that links strategic objectives and business processes to metrics.

3.1.1. Level 1: A set of various market scenarios and demands. Markets are unstable due to uncertainties in demands and supplies; therefore, strategies must be adjusted from time to time to reflect specific needs under specific circumstances. The market scenarios level includes various market demands, such as low demand, average demand, and high market demand. Each and every business faces one or different scenarios during a planning period. The reason to add market demand scenarios is to provide small businesses with the needed flexibility in selecting the right and accurate market demand in order to make adequate decisions on the next levels of the process (Alomar & Pasek, 2014).

3.1.2. Level 2: Set of major strategic attributes. This level considers the individual needs of a business. It provides small businesses with a wide-ranging set of strategic attributes (i.e., financial and non-financial attributes) that are essential for strategic thinking and actions. This level answers questions relating to strategy formation processes, such as the following: Where are we now? What do we need to achieve? This level includes major strategic attributes found in the literature—attributes such as, total cost, reliability, and the responsiveness of the system. The decision about which one is relatively more important depends on many factors, such as product type, market demand, and the type of competition and rivals (which has a strong connection to the previous stage).

3.1.3. Level 3: A set of business drivers. All processes and functions that are a part of business' value chain contribute to its success or failure of the business. These processes and functions work together to produce or make final products or services. Failure at any one process may lead to overall business failure. Failure at any one process or function may lead to overall failure. Therefore, each strategic attribute has to be linked and measured through the assigned area of success. For instance, if the focus is on reliability, one has to identify the most significant processes that will lead to increases or decreases in overall reliability. Thus, the model involves a set of business processes or major supply chain processes, such as sourcing, making or manufacturing, and deliveries or returns. The idea is to allow small enterprises to build a robust connection between and among business processes (success drivers), strategic directions, and external factors (markets). The processes in this level meet the major business area operations that are found in literature, such as in the supply chain processes constructed by the SCOR framework, for example. This level answers strategic questions concerning capabilities and resources.

3.1.4. Level 4: Key supply chain strategies. This level contains generic supply chain strategies based on the efficiency and responsiveness of the supply chain. However, one needs to understand the major differences between supply chains that are efficient and those that are responsive. For instance, on one hand, playing an efficient supply chain requires manufacturers to lower costs through the high utilization of resources, reduce lead time (but not at the expense of the cost), and select suppliers based on cost and quality. On the other hand, selecting a responsive strategy requires manufacturers to respond quickly to demand, maintain capacity flexibility to buffer against demand/supply uncertainty, and select suppliers based on speed, flexibility, reliability, and quality (Chopra & Mendle, 2010).

Similar to other works, the starting point begins with the overall goal or the business performance improvement process (stage 1). In the next stage (stage 2), the primary task is to estimate the likelihood of pre-defined market demand scenarios (i.e., low demand, average demand, and high demand). Next (stage 3), the main task is to identify and rank strategic attributes and measures (e.g., cost, reliability, and responsiveness). In stage 4, the primary task is to rank major areas of operations that support achieving high performance within various strategic attributes. In the next stage (stage 5), decision-makers may need to identify which business or supply chain strategy is most suitable to adopt in order to achieve the overall goal. An essential activity is the actual implementation of the selected strategy (stage 6). The last stage (stage 7) is based around the periodic review of the company's PMS.

3.2 Multi-Criteria Decision-Making (MCDM)

A performance measurement system can be seen as a multi-criteria instrument made of performance expressions (Melnyk, 2004). Therefore, conducting a multi-dimensional performance analysis involves solving a multi-criteria decision-making problem. MCDM or MCDA helps in organizing and simplifying multi-criteria decision problems in a systematic structure, which allows decision-makers to visualize problems in an understandable structure.

An MCDA is a sub-discipline of operations research that considers multiple levels, clusters, and criteria in decision-making situations. Several types of MCDA techniques are available, such as value engineering (VE), analytical hierarchy process (AHP), multi-attribute utility theory (MAUT), and analytical network process (ANP). Such techniques provide good approaches that allow for the quantification of decisions and prioritization of factors and elements that are crucial for the analysis, control, and improvement of business performance. Like other operation research approaches and implementations, in order to conduct and build an MCDA, one needs to understand and answer the following strategic questions:

1. What is the overall goal?
2. What are the internal and external factors (criteria) influencing the goal?
3. What are the options and alternatives available in order to support and lead the business to achieve that goal?

In this research, the Analytical Hierarchy Process (AHP) was considered. According to Saaty, the AHP approach assists in the following:

1. Structuring a problem as a hierarchy or a system
2. Eliciting judgments that reflect subjective decisions
3. Representing those judgments with meaningful numbers
4. Using these numbers to calculate the priorities of the elements of the system or hierarchy
5. Synthesizing these results to determine overall outcomes
6. Analyzing the sensitivity to changes in judgment

The Analytic Hierarchy Process (AHP), introduced by Saaty in 1971, has turned into one of the most extensively utilized technique for multi-criteria decision- making problems (MCDM) (Saaty, 2008). It is a decision-making approach proposed to aid in solving complex multiple criteria problems in a number of different application areas. AHP is a flexible problem-solving, and systematic method employed to represent the elements of a complex multi-criteria problem hierarchically (Chan et al., 2006).

The AHP methodology is a fundamental device for both managers and scholarly analysts which has been used to direct research for settling on business decisions and looking at management assumptions (Cheng et al., 2002). Unlike assigning weights approach, the AHP uses pairwise comparisons to develop precise ranking. The AHP has been used in comparing the overall performance of manufacturing departments (Rangone, 1996), manufacturing supply chains (Wang et al., 2005), benchmarking logistics performance (Chan et al., 2006), and vendor evaluation and selection (Haq &

Kannan, 2006). Other researchers are understanding that AHP is an important universal method and are applying it to a few manufacturing areas (Wang et al., 2005).

The AHP has several benefits. “First, it helps to decompose an unstructured problem into a rational decision hierarchy. Second, it can elicit more information from the experts or decision-makers by employing the pairwise comparison of individual groups of elements. Third, it sets the computations to assign weights to the elements. Fourth, it uses the consistency measures to validate the consistency of the ratings from the experts and decision-makers” (Cheng et al., 2002).

According to Saaty (1996), the human experience involves a very large number of intangibles. In general, and with few exceptions, intangibles cannot be measured on a physical scale. However, they can be measured in relative terms through comparisons with other tangibles or intangibles with respect to attributes they have in common, and a ratio scale can be derived from them that yields their relative measurement values. The attributes are themselves compared based on their importance with respect to higher attributes, the relative measures derived, and so on up to an overall goal (Saaty, 1996). The procedure of the AHP to solve a complex problem involves the steps in the figure below.

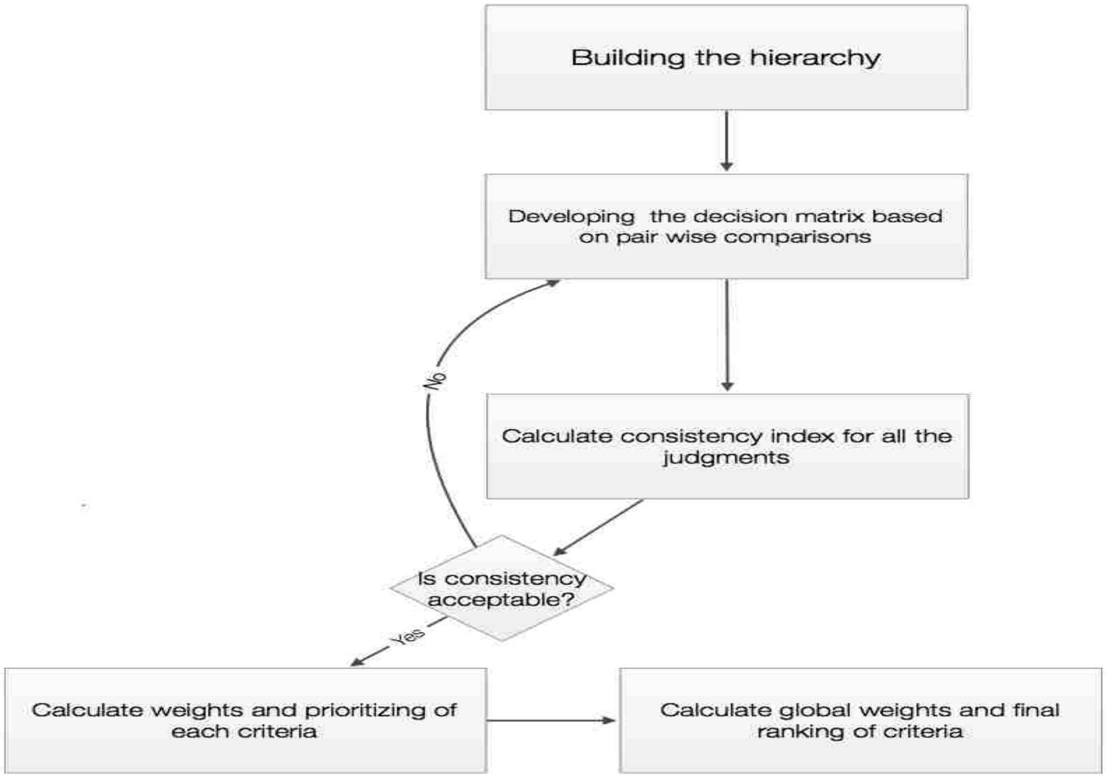


Figure 16. Steps involved in problem solving using the AHP approach.

3.2.1. Problem decomposition and hierarchy construction. Disintegrating the multi-criteria problem into levels or segments and then synthesizing the relations of the elements are the basic ideas of the AHP (see Figure 17).

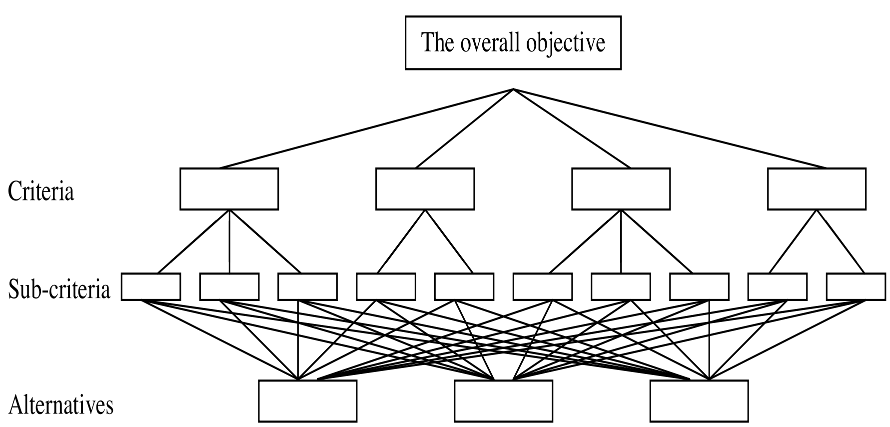


Figure 17. Basic structure of AHP heirichcal model.

3.2.2. Pairwise comparison and ratio scale. Pairwise comparison aims to determine the relative importance of the elements in all levels of the hierarchy. It starts from the second level and ends at the bottom level. A group of comparisons or comparison matrices of elements in a level of the hierarchy, with respect to an element at the directly higher level, are constructed in order to rank and translate individual comparative judgments into ratio scale measurements. The preferences are quantified using a nine-point scale. The importance of each scale measurement is explained in Table 10. The decision-maker needs to express a preference between each pair of the elements in terms of how much more important one element is than another element. For each and every level in the hierarchy, a pairwise comparison matrix is required in order to expresses individual and subjective judgments and preferences about all elements within the level, with respect to the upper level criteria.

Table 10

The Nine-Point Scale as Designed by Saaty

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities/factors contribute equally to the objective
3	Somewhat more important	Experience and judgment **slightly** favor one over the other
5	Strong importance	Experience and judgment **strongly** favor one over the other
7	Very strong importance	Experience and judgment **very strongly** favor one over the other.
9	Absolutely more/extremely important	The evidence favoring one over the other is of the highest possible validity
2 , 4 , 6 , 8	Intermediate values	When compromise is needed
Reciprocal	Opposite value	When task "*i*" has one of the above numbers assigned to it with task "*j*", then "*j*" has the reciprocal value when compared to "*i*."

The pairwise comparisons are obtained using the nine point comparison scale in Table 10. For instance, with respect to overall firm performance, which performance attribute or business process (N1 or N2) is more important/likely/preferable than the other is determined (see Table 11). Each cell in the table refers to the subjective judgment (i.e., N2 is extremely more important than N1).

Table 11

Pairwise Comparison within N Number of Elements

	N1	N2	N3	N4	Ni
N1	1	…	…	…	…
N2	9	1	…	…	…
N3	…	…	1	…	…
N4	…	…	…	1	…
Ni	…	…	…	…	1

According to Saaty, the pairwise comparison's reciprocal matrix of judgments produce the relative ratio scale which can be obtained by solving:

$$\sum_{j=1}^{n} aij * wj = \lambda max * wi \tag{3.1}$$

"Where $a_{ji} = 1/a_{ij}$ or a_{ij} $a_{ji} = 1$ (the reciprocal property). $a_{ij} > 0$ (thus, *a* is known as a positive matrix) whose solution, known as the principal right eigenvector, is normalized as in the following" (Saaty and Vargas, 2012):

$$\sum_{i=1}^{n} wi = 1 \tag{3.2}$$

However, it is not required to have a unit of measurement to measure the relative ratio scale. “When $a_{ij}\ a_{jk} = a_{ik}$, the matrix $A = (a_{ij})$ is said to be consistent and its principal eigenvalue is equal to n. The general eigenvalue formulation given above is obtained by perturbation of the following consistent formulation” (Saaty and Vargas, 2012):

$$Aw = \begin{matrix} & A1 & \cdots & An \\ A1 & & & \\ \vdots & & & \\ An & & & \end{matrix} \begin{bmatrix} \frac{w1}{w1} & \cdots & \frac{w1}{wn} \\ \vdots & \ddots & \vdots \\ \frac{wn}{w1} & \cdots & \frac{wn}{wn} \end{bmatrix} \begin{bmatrix} w1 \\ \vdots \\ w2 \end{bmatrix} = n \begin{bmatrix} w1 \\ \vdots \\ wn \end{bmatrix} = nw \qquad (3.3)$$

A has been multiplied on the right by the transpose of the vector of weights $w = (w_1, ..., w_n)$ resulted in *nw*. Consequently, to recover the scale from the matrix of ratios, we need to solve the problem Aw = nw or (A - nI)w = 0 (Saaty and Vargas, 2012). According to Saaty, the discrete formulation above can be generalized to the continuous case utilizing Fredholm’s integral equation of the second kind and is given by the following:

$$\int_a^b K(s,t)w(t)dt = \lambda \max w(s) \qquad (3.4)$$

$$\lambda \int_a^b K(s,t)w(t)dt = w(s) \qquad (3.5)$$

$$\int_a^b w(s)ds = 1 \qquad (3.6)$$

After creating the pairwise comparison matrix, the vector of priorities in the matrix has to be calculated and normalized to 1 or 100% by dividing the components of each column by the sum of the total of the same column. Then the eigenvector is obtained by adding the elements in each resulting row to obtain a row sum and dividing this sum by the number of elements in the row to obtain a relative weight.

3.2.3. Consistency check. One of the most important aspects of the AHP is that it allows one to measure the overall consistency of their judgments (a_{ij}). To measure the consistency in the pairwise comparison matrix, a constancy ration is used. Inconsistency may arise when λmax deviates from n due to inconsistent responses in pair-wise comparisons. Therefore, the purpose is to ensure that the judgments of decision-makers are consistent.

For a consistent reciprocal matrix, the largest eigenvalue is equal to the number of comparisons, or λmax = n, which can be measured by using consistency index formula (Saaty and Vargas, 2012):

$$CI = (\lambda_{max} - n) / (n-1) \quad (3.7)$$

$$\lambda max = \sum_i wi * ci \quad (3.8)$$

Therefore, the pairwise comparison matrix, the matrix A, should be examined for consistency using index CI above *CI* estimates the level of consistency with respect to a comparison matrix. Knowing the consistency index, the next question is how to use this index. Saaty suggests that the consistency index can be utilized by comparing it with the appropriate one. The random consistency index (RI) is the appropriate consistency index which involve randomly generated reciprocal matrix using scales of 1/9, 1/8, 1/7, …., 1 , 2, 3, 4, …, 8,9. The random consistency index is shown in the table below.

N	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Then, because *CI* is dependent on *n*, a consistency ratio *CR* is calculated, which is dependent on *n*:

$$CR = CI/RI \tag{3.9}$$

Where CR is the consistency ratio, CI is the consistency index obtained by equation (3.7), RI is random index (RI) generated for a random matrix of order n as shown in the table above. The overall consistency of a system or a hierarchy can be measured and checked by calculating the total sum for all levels with a weighted consistency index (CI) for the nominator and a weighted random consistency index (RI) for the denominator. The overall consistency of a hierarchy is determined by the following:

$$\sum_i wi\ CIi \Big/ \sum_i wi\ RIi \tag{3.10}$$

Checking consistency provides more information about the accuracy of the judgments, the pairwise comparisons and the decision alternatives selection (Anderson et al., 2008). The inconsistency measure is valuable for detecting likely errors in judgments as well as actual inconsistencies in the judgments themselves. Inconsistency measures the logical inconsistency of one judgment. For example, if one assumes that X is highly significant than Y and Y is highly significant than Z and then states that Z is highly significant than X, he or she is not being consistent. These judgments can be expressed in a more accurate way by assuming that X is 4.0 times more significant than Y, Y is 3.0 times more important than Z, and that Z is 9.0 times more important than X. The final score of decision alternatives can be obtained by applying the following equation:

$$S_k = \sum_{i=1}^{M} \sum_{j=1}^{N_i} W_i w_{ij} R_{ijk} \tag{3.11}$$

By using the AHP approach, one can construct, link, evaluate, and prioritize elements in a hierarchal structure that contains goals, criteria and sub-criteria levels, and alternatives or options. This also allows users to convert qualitative decisions into quantitative ones, which also helps in assessing and prioritizing elements according to their preferences and operation environments. Building the hierarchical structure and the connections among elements and levels of the model using the AHP approach is explained in the following points.

3.2.4. Adding market demand. Because business conditions have become more unpredictable and unstable, manufacturing firms are required to review operation strategies more frequently and conduct necessary adjustments and actions at the right time in order to meet these changes. A performance measurement system has to accommodate, capture, and reflect all types of external changes, such as market demand.

Because the majority of the production in small businesses depends on the number of available orders, businesses need to alter and reallocate their resources accordingly. Therefore, it is important to add a level or criteria that describe various market demands, and that is level 1. Level 1 includes low, average, and high market demand (see Figure 18). Level 0 is the goal level. It is the strategic goal a company wants to achieve. The process begins at level 1 by assessing the possibility and likelihood of different market demands during the planning period. At this level, one has to define which market demand or scenario is most likely to occur—low, average, or high. This determination can be made by examining orders on hand, forecasts, historical data, or sometimes based on intuition or feelings!

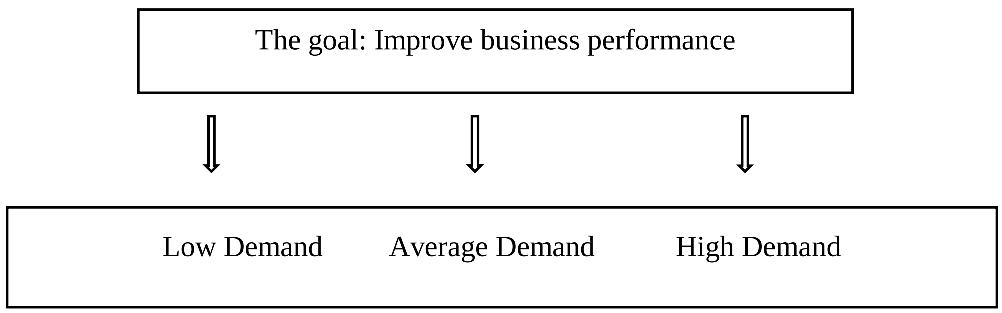


Figure 18. The first two levels using AHP structural approach.

However, it is extremely important to have some good information on hand about market trends, the behavior of the market, and the external factors that influence demand. It is also important for businesses to have demand classifications to differentiate levels of demand and assign classes for each one.

3.2.5. Adding the second level: Strategic attributes. A performance attribute is a combination of metrics used to express a strategy. However, an attribute itself cannot be measured; it is used to create a strategic direction for businesses (Supplychain.org, 2014). Businesses need to have solid, adequate, and correct information about their performance. Such information assists in directing actions and changing or adjusting goals, or maybe even in adjusting the overall strategy. However, it is essential for businesses to decide what to measure and how to measure it in order to execute correct decisions and actions.

It is not unusual to find businesses that measure and focus on attributes that do not reflect their strategies or actual market needs or that do not use the correct metrics to measure those attributes. Such practices misguide businesses and could lead to improper planning of control and improper management and actions.

The literature highlighted the fact that a strategic performance measurement system must link strategic planning to strategic attributes. However, most of the previous studies conducted on performance measures in small enterprises emphasized the use of operational measures but not the strategic ones, see Figure 19. The figure shows some of the main measures retrieved from the previous studies. However, these measures can also be used indirectly in calculating strategic attributes. At the strategic attributes level, a broad metric that can be used to check strategy implementation processes is required. For example, the quality of processes, products, deliveries, and error-free processes can all be combined with other measures to formulate business reliability. Process time, ordering time, and delivery time can be categorized under responsiveness time. Accordingly, a set of strategic attributes were considered. Table 12 below shows the selected strategic attributes. The cost is considered as an internally-focused or financial attribute, and reliability and responsiveness are considered as customer-focused or non-financial attributes. These are level 1 metrics that represent strategic directions and performance attributes.

As discussed earlier, level 1 involves strategic metrics that are not measures by themselves. Level 2 metrics are used to make the calculations of level 1 metrics and to measure how successful the business is in achieving its desired position within a competitive market. For example, the reliability attribute addresses the ability of the business to perform tasks as expected. It focuses on the predictability of the outcomes of the processes. In reliability, the key performance indicator is the order fill rate, which includes, for example, measuring the correct quality and quantity of deliveries.

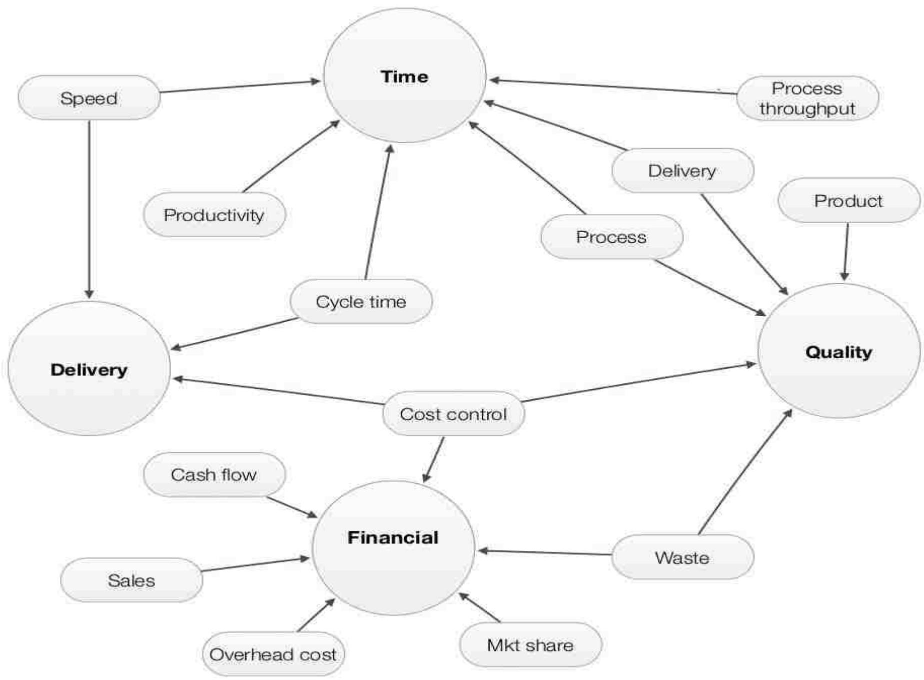


Figure 19. Links among major performance measures.

Table 12

Definitions of the Selected Strategic Attributes

Strategic Attributes	Definition
Cost : **CO**	The cost of operating the business and or supply chain processes.
Reliability: **RL**	The ability to execute tasks and activates as planned or expected. It focuses on the outcomes of the processes
Responsiveness: **RS**	The speed at which tasks and activities are performed

Source: Supplychain.org, 2014

The structure of the model so far is shown in Figure 20. Up to this point, the model attempts to achieve the main goal by integrating and connecting various market scenarios, and performance attributes. It is absolutely incorrect to trace and focus on particular attributes while overlooking others, and it is also not a correct strategy to emphasize few attributes regardless of market behavior. Therefore, each and every market scenario and demand scenario has it is own challenges and circumstances. Each needs a different strategy, actions, and measures.

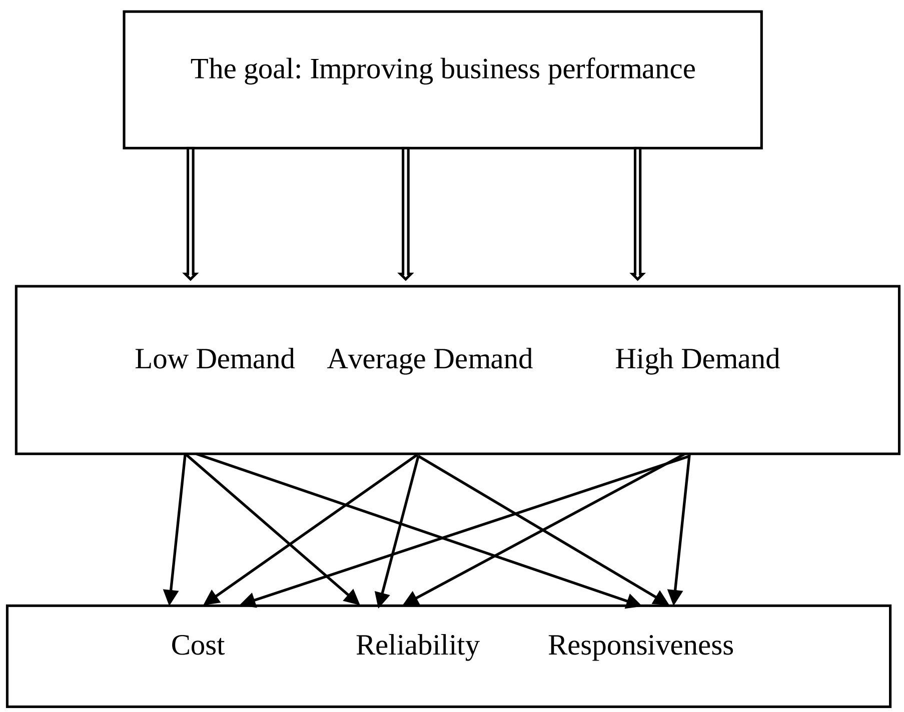


Figure 20. Market demands, strategic attributes, and processes in three connected levels.

3.2.6. Adding drivers: Adding processes. A process is a unique activity performed to meet a pre-calculated outcome (see Table 13). At this level, the model is supported with a set of business process areas based on a generic supply chain process structure (supply chain.org, 2014). It contains sourcing, making or manufacturing, and delivery and returns. The idea behind this level is to increase the ability of small enterprises to connect processes to strategic attributes and vice versa. The processes included in this level meet the major business processes found in the literature. Although these processes can be divided to sub-process levels, the proposed methodology recommends the use of only the main levels of processes as starting points for the decision analysis process.

Table 13

SC Processes and Definitions

SC Process	Definition and Objectives
Source: **S**	The ordering, delivery, receipt and transfer of raw material items, subassemblies, product, packaging or service
Make: **M**	The conversion process of adding value to products through mixing, separating, forming, machining, and chemical processes, repair ...etc.
Deliver: **D**	Perform customer-facing order management, shipping, and order fulfillment activities including outbound logistics.
Return: **R**	Moving material from customer back through SC to address defects in products, ordering, and manufacturing or to perform maintenance activities.

Source: (supply chain.org, 2014)

At this stage, the assessment process evaluates the relative effect and importance of each sub-criterion of the supply chain process on attributes under specific scenarios. For example, what would be the relative effectiveness of the source, production, delivery, and return on overall performance and cost under high demand? Notice that the relative effects of each sub-criterion or process may vary depending on market conditions and the importance of the process under a particular performance measure. Therefore, a link is established among the three levels, as shown in Figure 21.

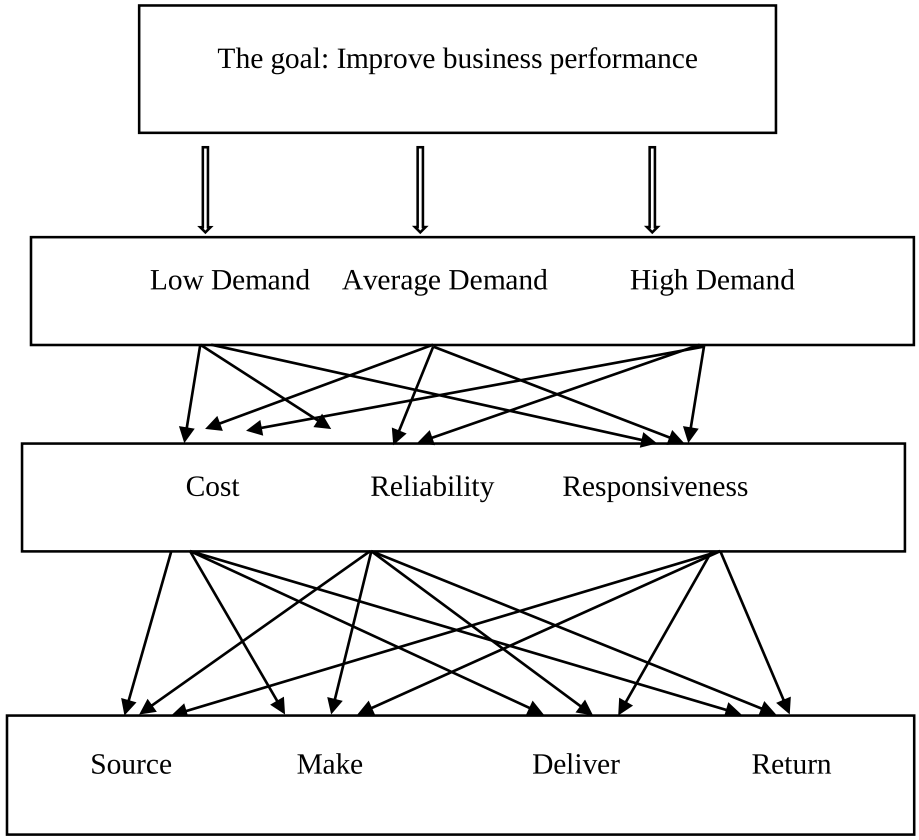


Figure21. Performance improvement model with three levels including strategic attributes.

3.2.7. Adding alternatives: Efficient and responsive supply chain. At this stage of developing a performance improvement model, two generic types of supply chain strategies were added to the model—efficient and responsive supply chain strategies (as shown in Figure 22). There are major differences in functional strategies between those that are efficient and those that are responsive, in regard to supply chains (Chopra & Meindl, 2010).

On one hand, for example, in stable market conditions, the manufacturing strategy is to lower costs through high utilization. The supply strategy is based on cost and quality. On the other hand, in dynamic market conditions, the manufacturing strategy is to maintain capacity and flexibility to buffer against demand/supply uncertainty, and the supply strategy will be based on flexibility, speed, reliability, and quality (Chopra & Meindl, 2010). The proposed model constructs a strategic and flexible performance measurement system that satisfies the major requirements of a multi-dimensional performance measurement system and constructs links among performance attributes and processes to various market demands and supply chain strategies.

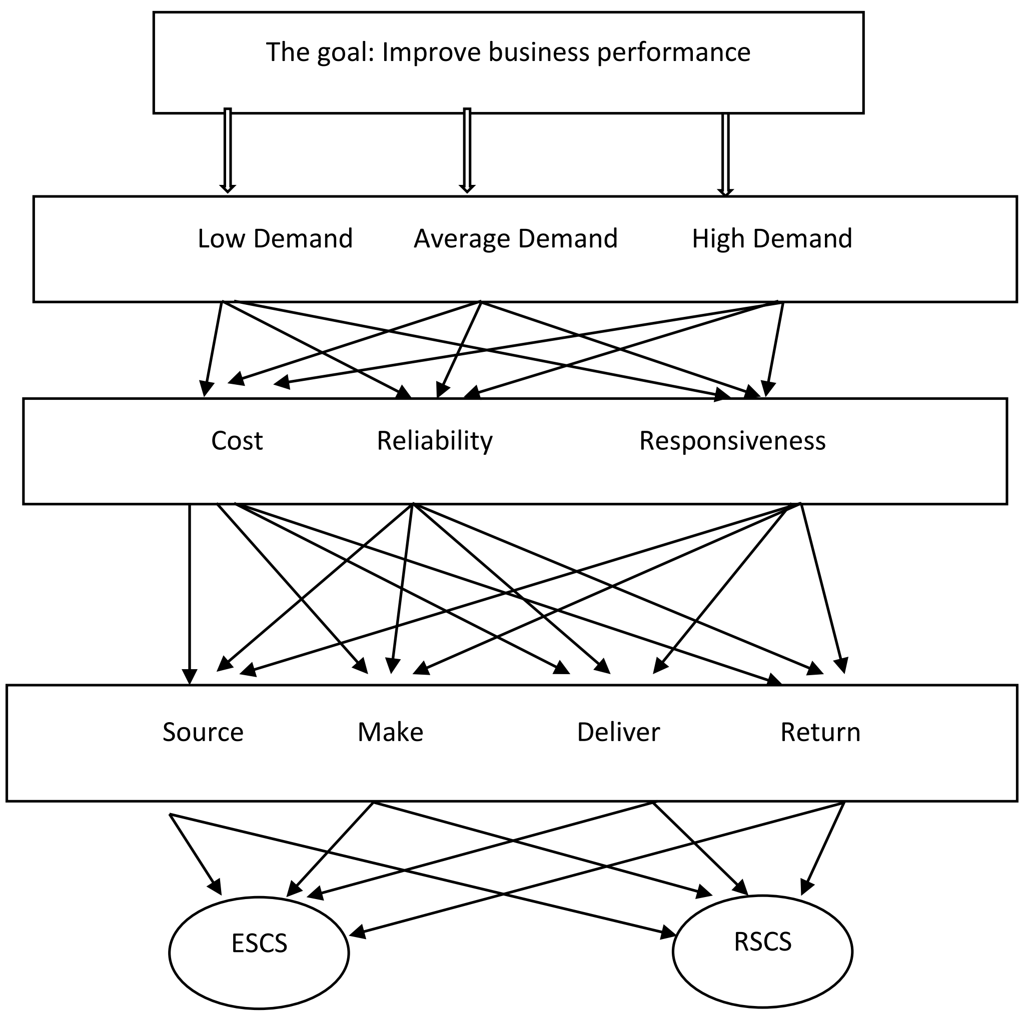


Figure22. The hierarchical structure of the proposed performance Measurement and improvement model using AHP methodology.

3.3 Verification and Implementation of Proposed Model

3.3.1. Verification of the model. The structure of a hierarchy or network is a way of representing a real-world problem. Certain characteristics make it difficult to validate the structures of hierarchies and network models. However, there are two methods that can be used to validate the structure of a model: logicality and completeness (Saaty, 2009). The proposed model matches the specifications and assumptions of the conceptual model for the given purpose of application. The model systematically represents the interactions among the elements and their strengths. The model was tested, and no errors in implementation were found. The model was also checked by experts in MCDM and AHP modeling. Moreover, the model outputs were checked using a variety of settings of the input parameters that meet the expected outputs.

3.3.2. Case study: Background. The practical evaluation process of the model was conducted by an SME. This enterprise is family-owned. It is a small manufacturing company with about one-hundred employees. The major products of this enterprise are construction and building materials. The major material suppliers are located in the region and supply approximately 60% of the required raw materials. The other 40% of the raw materials (resins) are obtained from Europe. The cost of raw materials depends on oil prices, supplier location and transportation costs, and associated inventory costs.

The majority of the company’s clients are locally located, and the majority of the outputs go to local government and major projects. The manufacturer faces high market demand, especially at the beginning of each year until the end of the second quarter. However, the market demand rises again at the end of third quarter through the middle of the fourth quarter. During high market demand, the manufacturer tries to satisfy the demand by utilizing production capacity and by maintaining acceptable inventory levels of different types of products. However, many backlog orders, incomplete deliveries, and longer cycle times frequently occur during peak periods. In many instances, the backlogs and incomplete deliveries lead to customers canceling their orders for the remaining quantities.

Usually, the manufacturer receives orders from a single client, which is generally a marketing enterprise that has an exclusive contract with the manufacturer. The manufacturer holds the responsibility to deliver the required quantities at the right quality to the right customers at the right time. Moreover, the manufacturer is totally responsible for transportation and delivery of the required items, and the returns of defective products and errors.

In term of internal systems and procedures, the manufacture considers the quality and reliability of its processes as a priority to run the business. The manufacturer is certified for ISO and implements rigorous standard operating procedures to satisfy the quality requirements. In terms of performance measurement, the financial measures are considered as the most important resource of information in the strategic decision-making process. Although the manufacturer has too many other non-financial measures, they do not seem to have an impact on strategic decisions inside the enterprise. As a matter of fact, many of the internal measures are used to provide figures on operational performance and day-to-day operations, without taking into consideration the strategic ones. For example, the manufacturer has records about the amount of rejection and defective products and returned shipments, but they do not have any index for the reliability of processes.

3.4 The implementation and Analysis

3.4.1. Implementation Process. The execution process of the model begins at level 1 by assessing the occurrence of different market demands during the planning period. At this level, one has to ask the question, “Which market demand or scenario is most likely to occur—low, average, or high?” This question can be answered by looking at orders on hand, forecasts, historical data, or sometimes based on intuitions or feelings. It is absolutely important to have appropriate information on hand about market trends, the behavior of the market, and the external factors that influence demand. For example, in the case of the manufacturer, the company follows the demand categories in Table 14.

Table 14

Demand Categories for the Company

Demand	Low	Average	High
Weight (tons)	0-2499	2500-4999	5000 up

Based on the AHP scaling table and the pairwise comparisons, the input value of each comparison (i.e., low to average and average to high demand) entered by the enterprise decision-maker is shown in Table 15.

Table 15

Summary of the Enterprise’s Pairwise Comparisons of the Market Demands Level

Pairwise Comparison	Possibility of Demand	How Much More	Numerical Rating
Low-Average	Average	Moderately to strongly	4
Low-High	High	Moderately	3
Average-High	High	Equally to moderately	2

In order to determine the priorities for the market demand scenarios, we constructed a matrix of the pairwise comparison ratings provided in Table 16. Using the three criteria, the pairwise comparison matrix will consist of three rows and three columns, as shown below in Table 16. Because the diagonal elements are comparing each criterion with itself, the diagonal elements of the pairwise comparison matrix are always equal to 1. For example, if low demand is compared to low demand, the verbal judgment would be that they are “equally possible,” with a rating of 1. The other values in Table 16 show the reverse of the original ones. For example, when rating between average and low, the rating equals 4, and when rating between the low and average, the rating equals 1/4.

Table 16

Pairwise Comparison Matrix of Level 1 Elements

	Low	Average	High
Low	1	1/4	1/3
Average	4	1	1/2
High	3	2	1

The importance of each element can be computed in terms of its significance to the overall goal by using the pairwise comparisons among all elements in the hierarchy. This aspect of the AHP methodology is referred to as *synthesiation*. The synthesization process as cited in Saaty’s publications and other researchers follows the following steps:

1. Calculate the sum of the values in each column of the pairwise comparison matrix.

Table 17

Column Sum of Criteria

	Low	Average	High
Low	1	1/4	1/3
Average	4	1	1/2
High	3	2	1
Sum	8.000	3.250	1.833

2. Divide each component in the pairwise comparison matrix by its column's total sum. The obtained matrix is referred to as the normalized pairwise comparison matrix.

Table 18

Results of Step 2, the Normalized Pairwise Comparison Matrix

	Low	Average	High
Low	0.125	0.077	0.182
Average	0.500	0.308	0.273
High	0.375	0.615	0.546

3. Compute the average of the elements in each row of the normalized pairwise comparison matrix; these averages provide the priorities of the criteria.

Table 19

AHP Step 3 Results, the Priorities of Criteria

	Low	Average	High	Total row	Priority
Low	0.125	0.077	0.182	0.384	0.124
Average	0.500	0.308	0.273	1.080	0.359
High	0.375	0.615	0.546	1.536	0.517

The result of the market demands evaluation process shows that the possibility of the occurrence of the high demand scenario is relatively higher than the others. As shown in Figure 23, the high market demand is the most likely scenario, with a 52% probability. As previously mentioned, the comparison and evaluation depend on many factors and; in this case it, depends on orders on hand for the coming few months.

An important consideration in the pairwise comparison process is the consistency of the pairwise judgments provided by the decision-maker. With many levels and criteria in the hierarchy that associated with many pairwise comparisons and matrices, perfect consistency is a challenging subject. As mentioned earlier, the AHP provides a technique for assessing the consistency among the pairwise comparisons provided by the decision-maker.

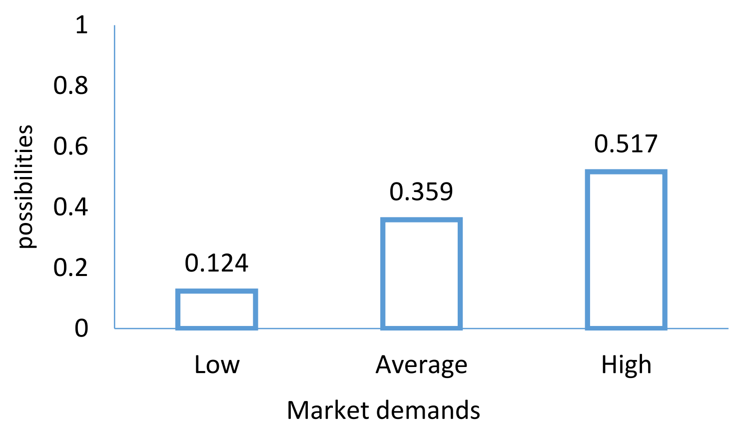


Figure23. The likelihood of different market scenarios.

If the degree of consistency is unacceptable, the decision-maker has to review their judgments. In order to measure the consistency, the consistency ratio is calculated. For example, if the consistency ratio is more than 0.10, or 10%, it indicates an inconsistency in the pairwise judgments. The consistency calculations as cited in Saaty's publications and in other publications follow the following steps:

Step 1. Multiply the values in the first column of the pairwise comparison matrix by the importance of the first item then multiply each value in the second column of the pairwise comparison matrix by the priority of the second item. Continue this process for all columns of the pairwise comparison matrix, and then sum the values across the rows to get a vector of values, or weighted sum.

$$.124 \text{ x} \begin{Bmatrix} 1 \\ 4 \\ 3 \end{Bmatrix} + .359 \text{ x} \begin{Bmatrix} 1/4 \\ 1 \\ 2 \end{Bmatrix} + .517\text{x} \begin{Bmatrix} 1/3 \\ 1/2 \\ 1 \end{Bmatrix} =$$

$$\begin{Bmatrix} 0.124 \\ 0.496 \\ 0.372 \end{Bmatrix} + \begin{Bmatrix} 0.090 \\ 0.359 \\ 0.718 \end{Bmatrix} + \begin{Bmatrix} 0.172 \\ 0.259 \\ 0.517 \end{Bmatrix} = \begin{Bmatrix} 0.386 \\ 1.114 \\ 1.607 \end{Bmatrix}$$

Step 2. Divide the components of the weighted sum vector obtained in step 1 by the corresponding priority of each criterion:

Low market demand	=	0.386/ .124 = 3.11
Average market demand	=	1.114/0.359 = 3.10
High market demand	=	1.607/0.517 = 3.11

Step 3. Compute the average of the values obtained in step 2. This average is denoted by λ_{max}.

$$\lambda_{max} = (3.11+3.10+3.11)/3 = 3.11$$

Step 4. Compute the consistency index CI as follows:

$$CI = (\lambda_{max} - n) / (n-1) = (3.11-3) / (3-1) = 0.055$$

Step 5. Compute the consistency ratio, which is defined as follows:

$$CR = CI/RI$$

As mentioned earlier, the value or RI depends on the number of items being compared. Table 20 provides us with the value of RI (RI= 0.58) when number of compared elements are 3.

Table 20

Values of RI and n Number of Compared Elements

n	*3*	*4*	*5*	*6*	*7*
RI	0.58	0.90	1.12	1.24	1.32

Therefore, CR = 0.055/ 0.58 = 0.095, and 0.095<0.10. Thus, the consistency ratio is acceptable.

Next the model attempts to integrate and link the main goal and various market scenarios to strategic attributes. The calculation of the following levels will be conducted using Expert Choice software. “Expert Choice is intuitive, graphically based, and structured in a user-friendly fashion, so it is valuable for conceptual and analytical thinkers. Expert Choice software is intended to help decision-makers and software users overcome the limits of the human mind to synthesize qualitative and quantitative inputs from multiple participants” (Expert Choice, 2014).

Using the software, one assesses the importance and the effects of each criterion attribute on performance under a specific scenario, such as the relative importance of cost (CO), reliability (RL), and responsiveness (RS) on performance if demand is high, for example. The pairwise calculations are shown in Table 21.

Table 21

The Pairwise Comparison of Performance Attributes under High Market Demand

	CO	RL	RS
CO	1	1/2	1/4
RL	2	1	1
RS	4	1	1

The results obtained from the synthesizing process of performance attributes are shown in Figure 24. The results show that the responsiveness of the system is vital, and thus, the focus on this attribute is an appropriate strategy. Notice that the relative effects and importance of each performance attribute or criterion may vary depending on market conditions or product types.

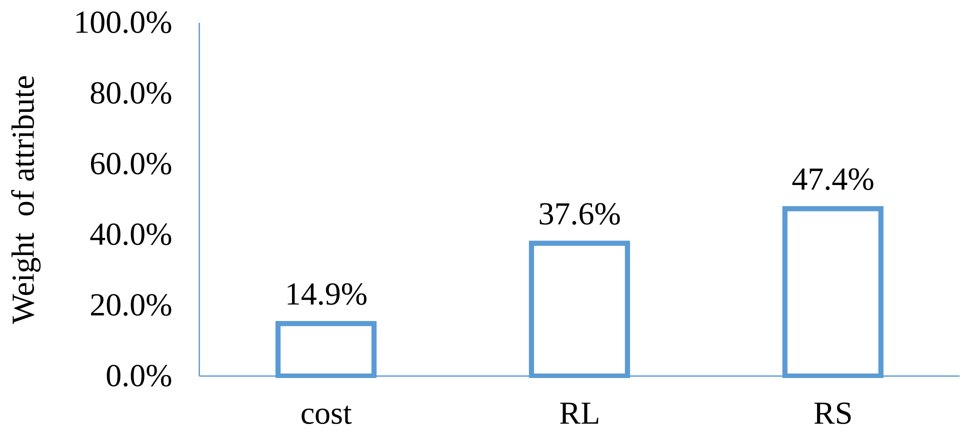


Figure24. Weights of performance attributes under high market demand.

So far, the pairwise comparisons for market demand and the strategic attributes have been calculated. In the next step, one needs to assess the relative effects and importance of each sub-criterion, or business process, on attributes under specific scenarios. For example, the relative effect and importance of source, make, delivery, and return on overall performance under responsiveness and high demand must be determined. Notice that the relative effects of each sub-criteria process may differ depending on market conditions and the importance and capabilities of the process under particular performance measures.

Figure 25 shows the importance and the impact of each business process under various strategic attributes with respect to high market demand. For the manufacturer, this means that the focus on the make, or manufacturing, processes is the major player for the reliability and responsiveness of the business in order to meet high demand and to satisfy customers.

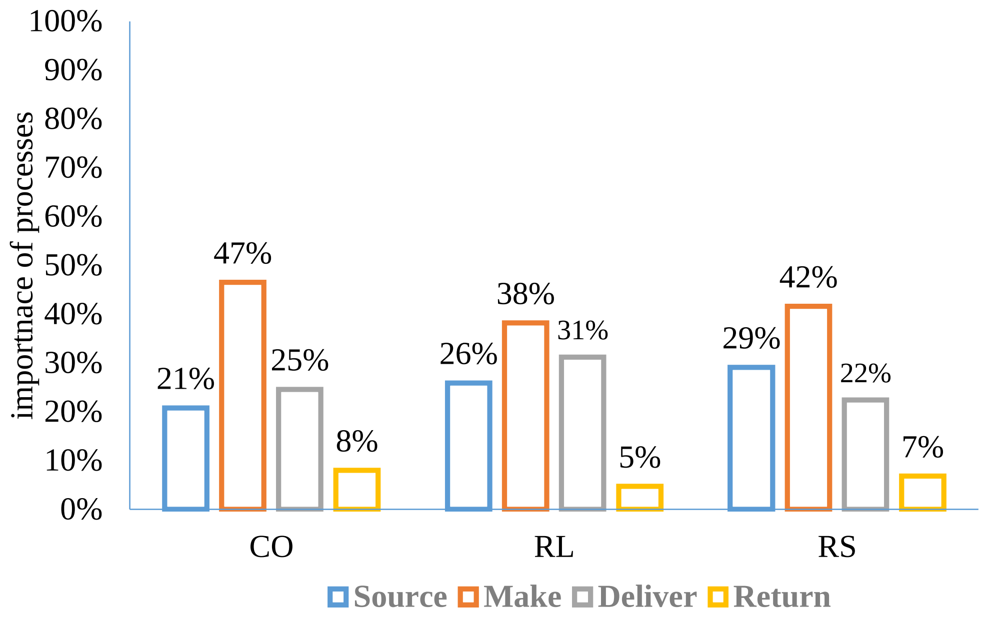


Figure 25. Distribution of business process under various strategic attributes in high market demand.

Because the responsiveness and reliability of the system comes first at high market demand, the manufacturer has to focus on the make and source processes for the responsiveness of the system and on the make and deliver processes for the reliability of the system (Table 22). Finally, one may connect all of these factors to the final stage, which is the selection of one of the available generic strategies—efficient or responsive.

Table 22

Importance of Business Processes under High Market Demand

	RL	RS	CO
S	10%	14%	3%
M	14%	20%	7%
D	12%	11%	4%
R	2%	3%	1%

Figure 26 reveals that the responsive supply chain strategy is most favorable when the business encounters high market demand, but what if the demand is not high as expected? Does the company need to follow the same strategy or adjust the strategy? Does the company need to focus on the same set of strategic attributes? Does the focus on these selected processes achieve success for the business when operating within different market environments? What would be the required changes, and how can one make adequate decisions and actions that fit and meet the changes?

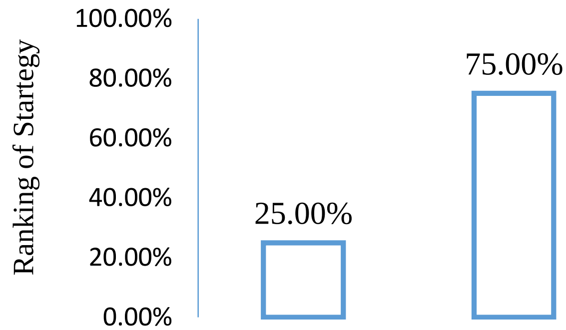


Figure 26. Weight of the two alternatives in high market demand.

3.4.2. Testing different scenarios. As the external environment changes frequently and rapidly the group of performance attributes and processes in use by businesses may also change to reflect these changes in internal and/or external environments. Generally speaking, the changes to the performance measurement systems can be done by adding, eliminating, replacing, or even reprioritizing criteria or factors. For example, a performance measure, such as responsiveness, which initially has a high priority, may move down to low priority in other circumstances or as a result of changes in the internal and/or external business environment (Alomar & Pasek, 2014).

In order to assess the changes and the sensitivity of the changes on the model outputs, one has to adjust the input parameters to different values. First, 100% occurrence of low market demand is considered. By doing the same pairwise calculations using Expert Choice software, we obtained the following rankings of the strategic attributes.

Notice that, in high market demand, responsiveness was the most significant, while in low market conditions, the cost was most significant. These results match the outcomes obtained from similar models but with different sets of levels (Alomar, 2013; Alomar & Pasek, 2014).

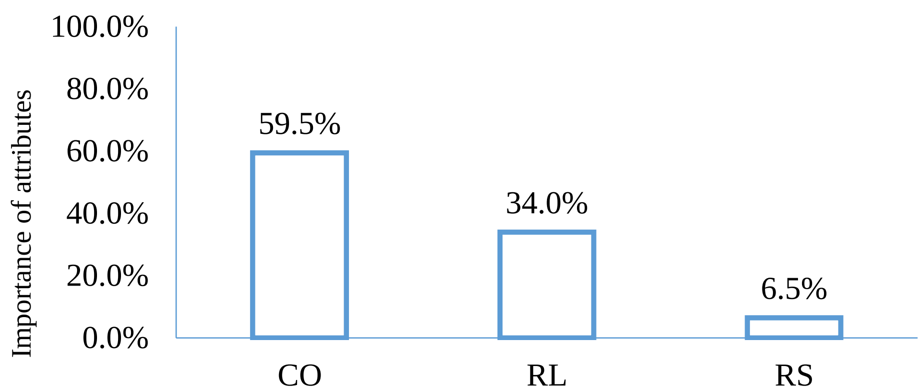


Figure 27. Ranking and importance of strategic attributes when demand is 100% low.

We need to assess the effects of the new scenario on business processes. Figure 28 reveals that the cost of source/supply has a direct and significant impact on total cost. Notice that the cost of the make, delivery, and return processes are relatively less significant due to the nature of the industry and the working environment. In fact, the cost of raw materials in this type of industry makes up more than 70% of the total cost; thus, reduction to the cost of sourcing is most appropriate. Moreover, the reliability of the make process is relatively more significant for increased cost reduction of total operations.

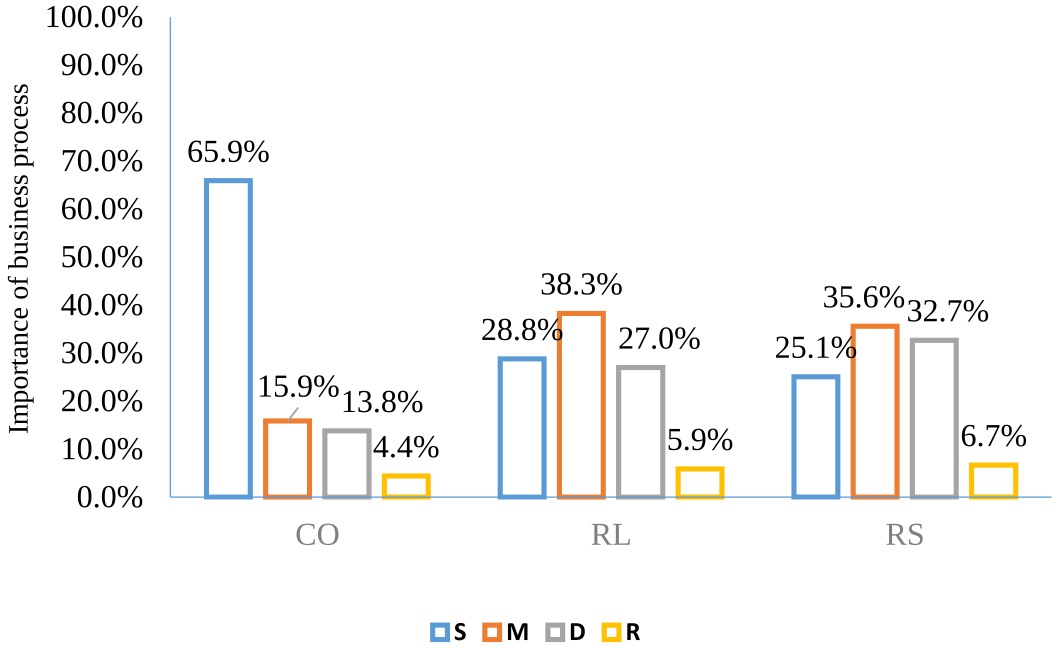


Figure 28. The importance of each business process under various strategic attributes in 100% low market demand.

Finally, a connection must be made between low market demand and one of the model's strategies. Under the 100% possibility of low market demand, the efficient strategy is the most appropriate one that also meets the requirements of operating the business with the lowest possible costs.

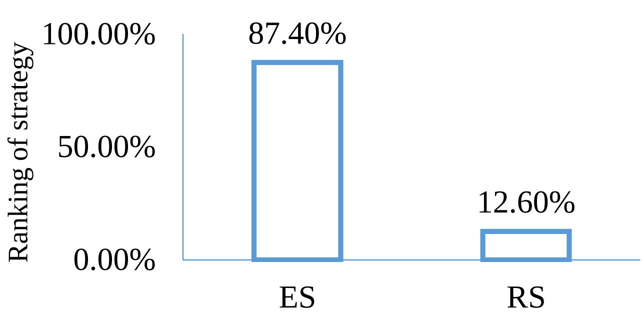


Figure 29. Selection and priority of strategy under low market demand.

However, when the market is exhibiting the 100% possibility of average demand, the results are relatively changed. The focus on reliability and responsiveness become higher at the expense of cost.

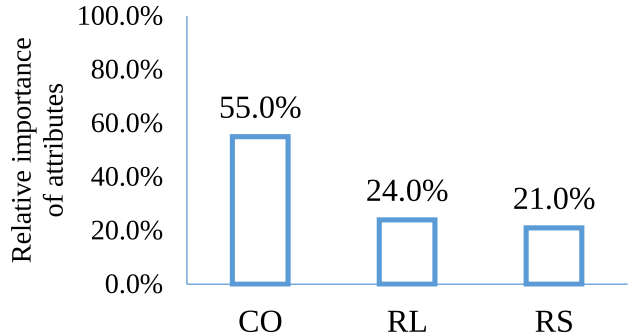


Figure 30. Relative importance of strategic attributes under average market demand.

In an average market demand scenario, the manufacturer needs to pay more attention to the source and make processes, in terms of cost, and to the make and delivery processes, in terms of reliability and responsiveness.

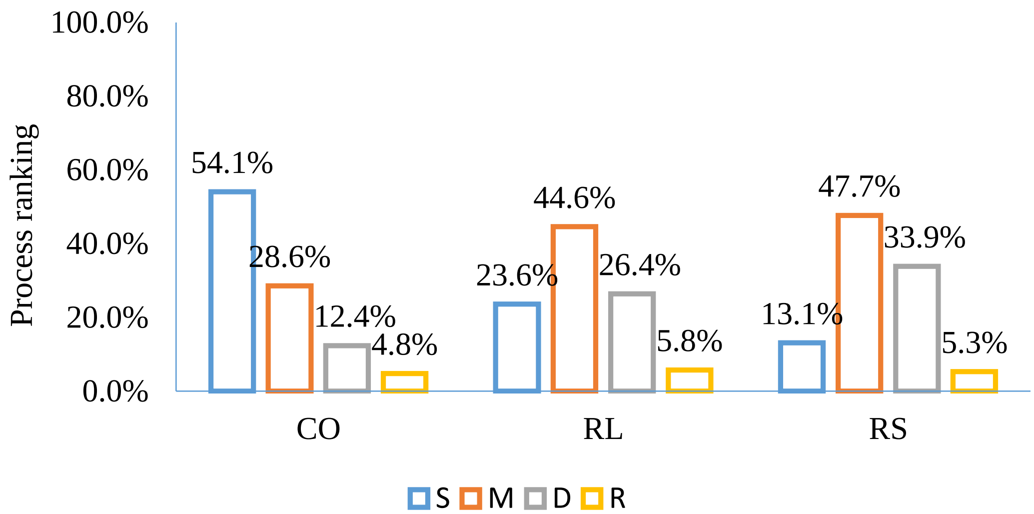


Figure 31. The importance of each business process under various strategic attributes in 100% average market demand.

The values and importance of strategies are shown in Figure 32.

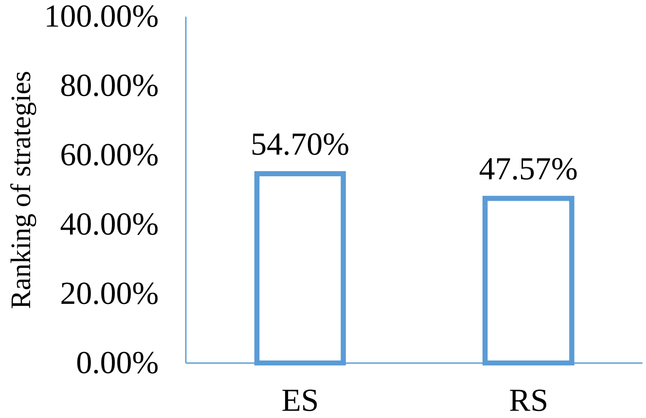


Figure 32. Selection and priority of strategy under average market demand.

Finally, the business may want to consider all the strategic attributes and all involved processes in order to have a complete performance measurement system. However, the experiment and the calculations show that the performance measurement system and the measures have to change accordingly with changes in the external environment (i.e., market demand).

For example, in Table 23, the performance measurement system involves all attributes and processes that a business believes are important. Nevertheless, when the market is low, the performance measurement system needs to pay attention to fewer parameters, including the cost and reliability of sourcing, and the reliability of the make process as well. When the market is high, however, the priority of the performance measurement system is the responsiveness and reliability of the source, make, and delivery processes (see Tables 24, 25, and 26).

Table 23

Performance Measurement System before Making the Assessment

Attribute\ Process	Source: S	Make: M	Deliver: D	Return: R
Cost: CO	x	x	x	x
Reliability: RL	x	x	x	x
Responsiveness: RS	x	x	x	x

Table 24

Important Measures in Low Market

Low MKT	Source: S	Make: M	Deliver: D	Return: R
Cost: CO	x			
Reliability : RL	x	x		
Responsiveness: RS				

Table 25

Important Measures in Average Market

Average MKT	Source: S	Make: M	Deliver: D	Return: R
Cost: CO	x	x		
Reliability : RL		x	x	
Responsiveness: RS		x	x	

Table 26

Important Measures in High Market

High MKT	Source: S	Make: M	Deliver: D	Return: R
Cost: CO				
Reliability : RL	x	x	x	
Responsiveness: RS	x	x	x	

Likewise, the weight and ranking of the strategy used depends on the market scenario. As shown in Figure 33 and Figure 34, the company needs to efficiently conduct its operations in order to improve performance, maintain a competitive advantage, and compete successfully. The results also verify Fishers' (1997) idea about the link between product types and the type of supply chain strategy to use. According to Fisher, efficient supply chain strategies work well with functional types of products. This has been proven through the case presented (Alomar & Pasek, 2014). However, in some circumstance (e.g., high market demand), the responsive system might work better than the efficient one (as seen in Figure 35).

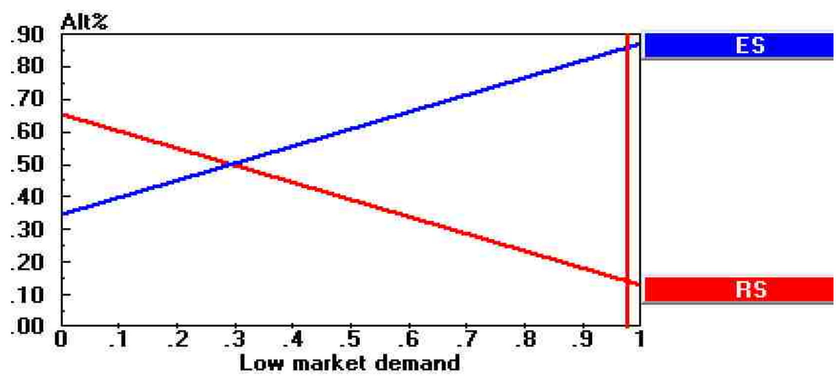


Figure 33. Selection of strategy under low market demand.

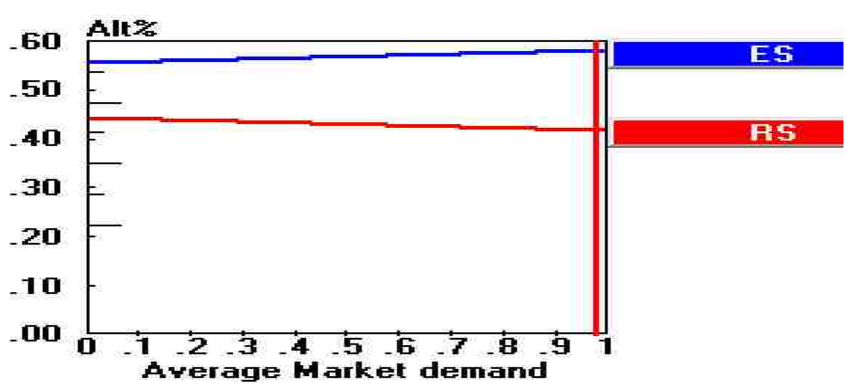


Figure 34. Selection of strategy under average market demand.

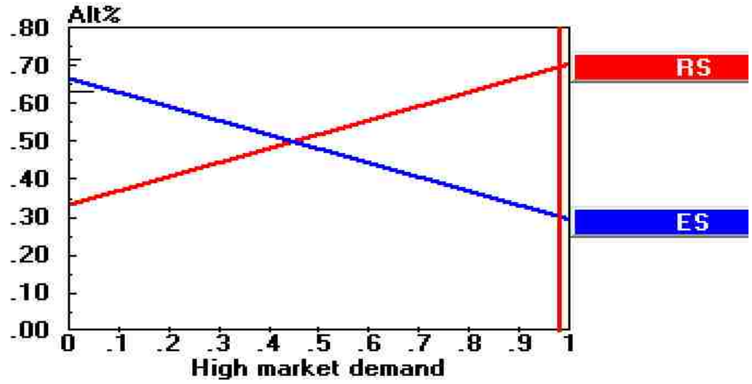


Figure 35. Selection of strategy under high market demand.

In a hierarchical model, like AHP, clusters are connected by arrows going in one direction from highest to lowest. However, these types of connections do not allow for the consideration of other interactions among nodes, clusters, or the internal elements in the model. Therefore, research needs to be done using an approach that allows for the evaluation and assessment of the effects and sensitivities of the interactions among the model's elements.

The strength of the analytic network process (ANP) allows one to take all kinds of connections and make accurate estimates and better decisions. The ANP is a mathematical theory that makes it possible to systematically deal with all kinds of dependencies and feedback.

The next step is to create an ANP model that involves all previously discussed levels and elements in the AHP approach. In addition, new connections among elements and levels will be added in order to measure the effects of interactions among them and to compare the results with those obtained from the AHP.

3.5 The Analytical Network Process (ANP)

The analytical network process (ANP) is a generalization of the analytic hierarchy process (AHP) because it considers the dependence between the elements of the hierarchy (Saaty, 2009). There are various decision complications cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower- level elements of the same hierarchy. One of the major strengths of the ANP methodology is the capability of taking the multiple dimensions of information into the analysis (Saaty, 1996). Therefore, the ANP is represented by a network not as a hierarchy. In ANP, the feedback structure does not have the top-to-bottom form of a hierarchy but looks more like a network (see Figure 36).

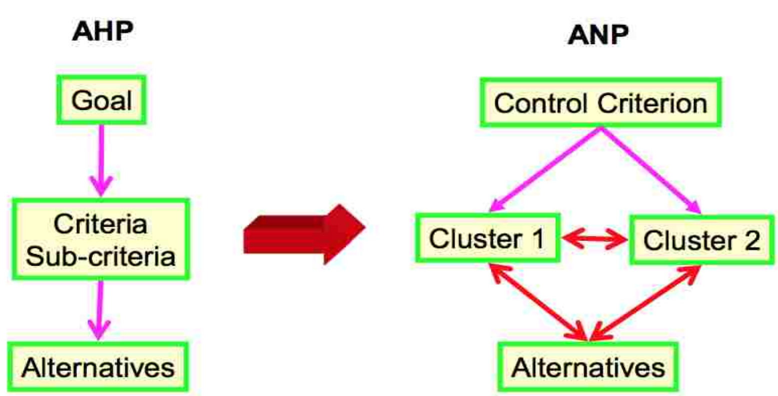


Figure 36. Converting AHP to ANP Model.

A full ANP network can include the following: source nodes; intermediate nodes that fall on paths from source nodes, lie on cycles, or fall on paths to sink nodes; and sink nodes. Some networks can contain only source and sink nodes. A decision problem involving feedback often arises in practice. It can take on the form of any of the networks described. The challenge is to determine the priorities of the elements in the network and, in specific, the alternatives to decisions. There are five major steps in applying the ANP method (Saaty, 1996). They are described in the following sections.

3.5.1. Network structure. Unlike the AHP hierarchical structure, a network structure must be developed presenting the relationships and interactions among the criteria that need to be analyzed. The decision network in the ANP does have an overall objective, clusters or groups, and criteria that need to be evaluated.

3.5.2. Pairwise comparisons. The pairwise comparisons among the criteria significantly influence the evaluation of criteria. Therefore, the ANP approach requires users to steadily place inputs by asking the relative importance of one criterion when compared to another criterion with respect to control criteria. Like in the AHP approach, the values allocated to the comparisons of the criteria must be within the range of one to nine.

3.5.3. Calculate relative and local weights. In this step, the relative importance-weight vectors of the criteria are calculated. From each pairwise comparison matrix achieved in step 2, compute the relative ranking of criteria with respect to the corresponding controlling criterion. Based on the input data collected from the practitioner for pairwise comparisons, the relative weights and local weights are calculated.

3.5.4. Development of supermatrix. Form and normalize the supermatrix. Form an unweighted supermatrix, and then normalize it so that the numbers in every column result in a sum of 1.0. The normalized supermatrix is the weighted matrix. The supermatrix is developed by incorporating the weights of the many criteria, and next, the supermatrix is normalized.

3.5.5. Priorities of the criteria. Determine priority values of each of the criteria. Raise the normalized supermatrix to a large power in order to calculate the converged weights of the criteria. To derive the overall priorities of the criteria, the weighted supermatrix is raised to limiting powers. Consequently, based on the priorities, the criteria may be compared, and the greatest criteria can be obtained.

3.6 Constructing a Model Using ANP Methodology

To construct an analytical network process model, the steps mentioned above must be implemented by primarily creating a network structure of clusters and nodes. This step includes considering the necessary connections among nodes and clusters. The structure of the ANP model follows the following steps.

3.6.1. Adding market demand and product type. Because business conditions have become more unpredictable and unstable, manufacturing firms are required to review operation strategies more frequently and conduct necessary adjustments and actions at the right time in order to meet these changes. A performance measurement system has to co-operate with all types of external changes, such as market demand, for example. Because production in small businesses depends on the available orders, businesses need to alter and reallocate their resources accordingly. Therefore, it is important to add a cluster that describes various market demands. The market demand cluster includes low, average, and high market scenarios (see Figure 37).

Businesses usually produce or offer different types of products or services. In general, they can be categorized as either functional or customized products or services. In the ANP model, the general form of product type is used. For instance, the enterprise in this research produces functional products that meet general standards and meet most

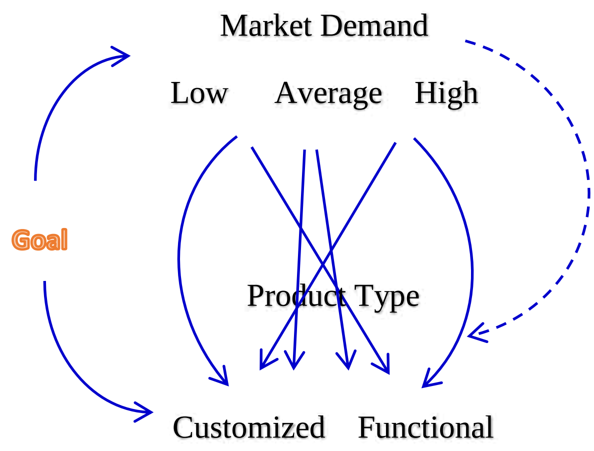


Figure 37. Connections among market demands and product type clusters.

of the regular market orders. Meanwhile, they also receive orders for customized products that, in addition to meeting the workable standards, must meet particular aspects specified by the customers. Because both functional and customized products and services are generally offered by businesses, a cluster that includes both types is appropriate. Within the model, users can select equal value, or simply input high values for the types of product(s) they produce. For example, a company may assign a value of nine to customized products because they greatly depend on customized products. Other enterprises might give high value to functional products because a high portion of their net profit comes from such products. Figure 37 above shows the first two clusters in the proposed ANP model. One cluster involves various market demands (i.e., low, average, and high market demands). The other cluster, product type, contains customized and functional products. In addition, the ANP model constructs a new connection between clusters that did not exist in the AHP model. The first cluster connection connects market demand and the product type, which allows businesses to make judgments about which cluster is more important than others.

3.6.2. Adding strategic attributes. As mentioned earlier, it is essential for businesses to realize what, when, and how to measure in order to execute correct decisions and actions. As in the AHP model, we are going to use some of the common strategic attributes found in literature. Cost is considered an internally-focused or financial attribute. Reliability and responsiveness are considered customer-focused or non-financial attributes. These metrics are the calculations with which a business can measure how effective it is in achieving its preferred position within the competitive market. For example, the reliability attribute addresses the ability of the business to perform tasks as expected. It focuses on the predictability of the outcomes of the processes. The key performance indicator is order fulfillment, which includes measuring delivery with the correct quality and quantity. The structure of the model so far is shown in Figure 38. Unlike the AHP model, in the analytical network process, the market demand, product type, and supply chain strategic attributes are connected. In the real world, there are strong and significant connections among market demand scenarios, strategic attributes, and product type attributes as well.

In fact, the decision about which attribute is more important than the other affects the whole supply chain and business processes. For example, when producing functional products, the main strategy is the economics of scale and the efficiency of the supply chain strategy, which in turn, focuses on cost reduction and, in the long run, on the cost factors. The economies of scale are the expense focal points and the cost advantages that businesses get due to size, yield, or size of operation, with expense per unit of output decreasing with expanding scale because fixed expenses are spread out over more produced units. However, the customized product types mainly depend on special customer orders that do not focus on cost, but rather on responsiveness and delivery. Reliability also plays substantial role in both cost and responsiveness.

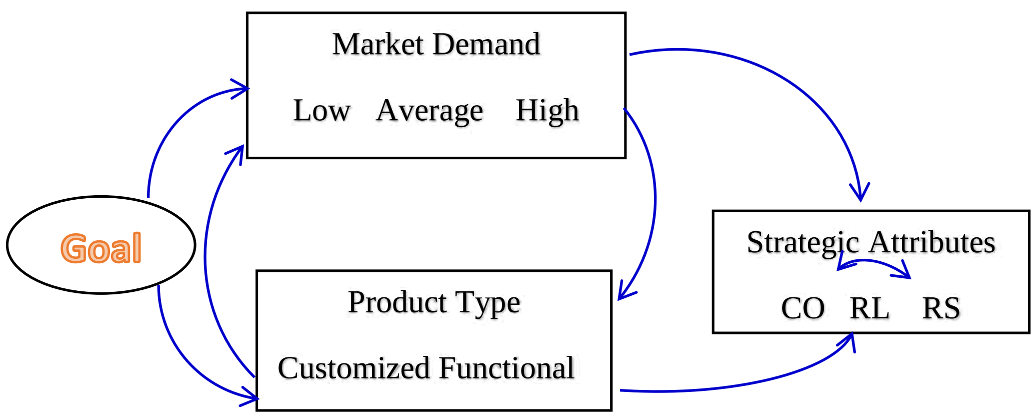


Figure 38. Market demand, product type, and strategic attributes.

The reliability of operations and products affect the whole processes and customer satisfaction. In order to compete in highly competitive markets, responsiveness time must also be lower than or equal to the responsiveness times of competitors; otherwise, there will be high risks that customers will move to competitors. Therefore, businesses are required to make judgments about these three major attributes in order to properly allocate their resources and gain advantages in various market scenarios and with different types of products. Accordingly, business owners need to decide and make judgments when producing customized product or functional products. They must decide which of the attributes (i.e., cost, reliability, and responsiveness) are more important than the others.

3.6.3. Connecting supply chain processes. The supply chain process in the ANP model contains sourcing, making or manufacturing, and delivery and returns. Adding supply chain process clusters aims to increase the ability of small enterprises to monitor various operations and to connect them to strategic attributes. Unlike in the AHP approach, the ANP connects clusters and nodes not as levels or hierarchical structure but in groups or clusters. The supply chain processes cluster is linked to strategic attributes, market demands, and product types. In addition, because there is a significant impact among processes, a loop connection is established.

Each process, in terms of cost, reliability, and responsiveness, depends on the former process or processes. The delivery process, for example, depends on the preceding processes (the source and make processes). In real life, the delivery schedule cannot be met if required materials or productions are not transferred to warehouses. Accordingly, the strategic attribute must be linked to the process or group of processes in order to achieve high performance. If the focus is on responsiveness, the decision on which area of the business or which processes are highly important and more critical than the others must be made. Another connection exists between product type and processes in order to identify the importance of each process to the type of product on hand. One more connection exists among the supply chain strategic attributes. The need for this connection is to satisfy the interrelation among them. For instance, the cost of operations might be affected by the reliability of processes and the quality of products. The more rejection that occurs during production time means higher operating costs and higher responsiveness times. Figure 39 shows all of the required connections among the existing clusters and the clusters themselves.

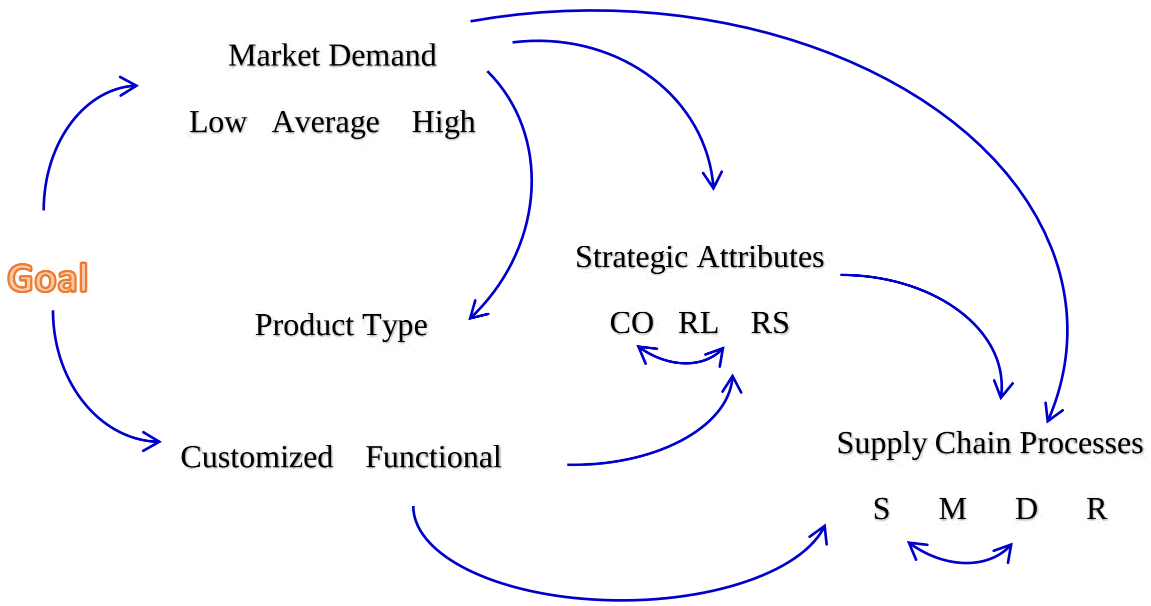


Figure 39. Connecting Processes Cluster to other clusters with internal loops.

3.6.4. Adding supplier criteria and concluding the connections. To finalize the connections and in order to build a comprehensive model, a supplier cluster is required. Supplier choice is the initial phase in the exercises in the item realization procedure, beginning from obtaining materials to the end of conveying the items. Supplier selection is evaluated as a critical factor for any businesses eager to be successful in current rivalry conditions. Adding the supplier cluster is important because business operations, strategies, and profits are strongly affected by the operations of suppliers, especially for businesses that have or depend on a single supplier. However, the significance of this cluster can be ignored by applying a low cluster value through the judgment process if the practitioner feels that it is necessary to do so. In our point of view, the importance of the supplier cluster must be high only when a business has no barging power over the supplier. It can be decreased when the type of material used in the operations can be obtained without difficulties and with low cost or when business can turn to other suppliers effortlessly. However, the supplier cluster can significantly assist businesses for whom operations and markets are rigorously dependent on their suppliers.

Figure 40 shows the constructed ANP model with all required clusters, nodes, and connections (market demand, product type, strategic attributes, business processes, and supplier criteria). It shows the interconnection among different clusters and loop connections as well. The model also demonstrates, in an understandable way, how the connections have been built and the importance and necessity of them as well. The model almost covers all aspects and major areas that small businesses need to focus on in order to improve performance.

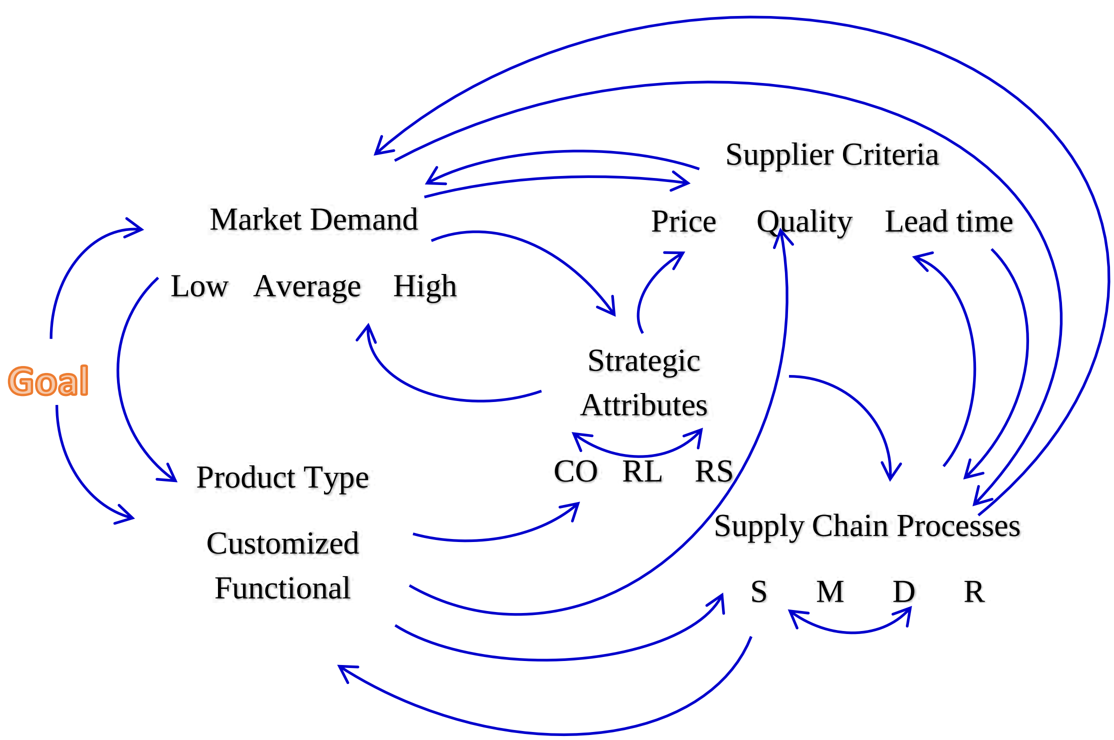


Figure 40. The propsoed anayltical netwrok process model shows clusters conections and loops.

This model also connects the strategic views of different businesses to all upstream and downstream operations, without omitting market demands or product types. In the following section, the ANP model will be introduced, implemented, and tested using small manufacturers' profiles and preferences.

3.7 Implementation and Analysis

Similar to the proposed AHP model, the proposed ANP model matches the specifications and assumptions of the conceptual model for the given purpose of application. The model systematically represents the interactions among the elements and their strengths. The model was tested, and no errors in implementation were found.

Moreover, the model outputs were checked using a variety of settings of the input parameters that meet the expected outputs. After constructing the ANP model, the user or the practitioner has to make judgments using pairwise comparisons among clusters and nodes, as described in step 2. For steps 2 to 4, Super Decisions software is used to insert judgments and pairwise comparisons for all clusters and nodes and to obtain final priorities. Super Decisions is decision-making software based on the analytical hierarchy process (AHP) and the analytical network process (ANP) (Super Decisions, 2015). The first few comparisons of market demand, product type, strategic attributes and processes are similar to the ones that were obtained in the previous section with the AHP model. However, with the complete connections among clusters, more pairwise comparisons are required.

The pairwise comparison process starts with the goal cluster. The practitioner is required to make the judgments with a desired goal in mind and with accurate figures that show the type of market demand in terms of quantities and product type. To start the judgment process, a comparison process between market demand and product type clusters, with respect to the overall goal, is conducted. Similar to the pairwise comparison processes conducted in the previous sections for the AHP model, users make the comparison by giving values and input parameters to the nodes and clusters.

Within the same comparison process, users also conduct node comparisons allocated to market demand and product type. For instance, practitioners make judgments with respect to high market demand and which product type has the highest priority, customized or functional. Similar judgments must be done for other market demand scenarios (average and high).

In Table 27, the management decided that the market demand scenario is strongly to very strongly more important than the product type. This was expressed by assigning a value of six to market demand. Other businesses may find that the type of goods they produce is more important than market demand because they face a stable market for their products. Likewise, the company has to decide what type of market condition (low, average, or high) is most likely to occur within the coming months. Table 28 shows the judgments and the preferences of the company with respect to the type of demand.

Table 27

Pairwise Comparison of Market Demand and Product Type

	Market Demand	Product Type
Market Demand	1	6
Product Type	1/6	1

High market demand is the most likely scenario that the company expected to encounter for the following few months. Table 28 reveals that the company studied anticipated approximately 52% high demand, 36% average demand, and 12% low demand (also see appendix). These judgments on market scenarios were based on the number of orders that they received for the coming few months and based on historical data for the same quarter of the previous year.

Table 28

Pairwise Comparison of Market Demand

	Low	Average	High
Low	1	1/4	1/3
Average	4	1	1/2
High	3	2	1

A similar comparison process was conducted by the company to find out which product type had more priority over the other and by how much. The types of products that are sent to customers show that the company is required to produce more functional products than customized ones. Therefore, the judgment gives more importance to functional products than customized products, as shown in Table 29 below.

Table 29

Judgments on Product Type with Respect to Goal

	Functional	Customized
Functional	1	8
Customized	1/8	1

To summarize the rankings of nodes and clusters that were obtained from the first few comparisons, the first two cluster comparisons show a high possibility for high market demand (52%) and high importance for functional types of products (approximately 89%). These are the local priorities obtained from the cluster comparisons. However, these priorities could change when different circumstances occur or simply when other practitioners or other enterprise place other values. Again, one might conduct the comparison process and place high value for customized products for all market scenarios due to the type of demand or as a result of the types of the products and operations within a firm.

What do these figures tell the manufacturers and the decision-makers in the companies and how can they be interpreted? These figures tell manufacturers and decision-makes that, during high demand, the company has to focus on the resources that support the production of functional products, such as processes, machines, manpower, moulds, and other related tools that are usually used to produce the functional products. They also show that raw materials must be available when needed, without delay or errors, which means that it is necessary to place more attention on source processes and supplier criteria than on other aspects. The figures also provide information about how delivery will look, which imposes another pressure for the tight delivery schedules.

Likewise, the comparison process that are obtained by adding the supply chain strategic attributes and supply chain processes follow the same concepts and procedures. In Table 30 below, the manufacturer inserted values among the previously identified strategic attributes with respect to a high market demand scenario. The practitioner made the judgments among the three strategic attributes (cost, reliability, and responsiveness).

This can help to address question regarding which strategic attribute is more important than the others under specific market conditions (i.e., cost or reliability, cost or responsiveness, or reliability or responsiveness).

Table 30

Pairwise Compariosn among Strategic Attributes with Respect to High Market Demand

	CO	RL	RS
CO	1	1/4	1/8
RL	4	1	1/3
RS	8	3	1

According to the judgments made, the company believes that responsiveness to customer orders is more important than cost and reliability when facing high market demand. Similarly, a practitioner may ask a question concerning which attribute is more important than the others for functional types of products. The judgments and results are shown in Table 31, which also demonstrates the judgments that were made based on the company's preferences.

Table 31

Supplier Criteria Comparison and Local Priorities with Respect to High Market Demand

-	Price	Quality	Lead Time
Price	1	1/4	1/4
Quality	4	1	1
Lead Time	4	1	1

Table 32 shows that, when functional products are in demand, the price of raw materials is more important than other factors.

Table 32

Supplier Criteria with Respect to Functional Product Type

	Price	Quality	Lead time
Price	1	1	8
Quality	1	1	6
Lead time	1/8	1/6	1

At this point, the manufacturer needs to make judgments about business processes with respect to high market demand. In this step, as shown in Table 33, the pairwise comparisons are conducted among the source, make, deliver, and return processes in order to see which ones have the highest impact when the market is high.

Table 33

The Pairwise Comparison of Process Cluster with Respect to High Market Demand

	Source	Make	Deliver	Return
Source	1	1/4	1/2	4
Make	4	1	2	6
Deliver	2	1/2	1	6
Return	1/4	1/6	1/6	1

For loop connection or dependency judgment, as shown in the supply chain processes cluster in Table 34, the manufacturer has to decide which process is more important than the others with respect to the deliver process in the same cluster. The preceding processes are the source and make processes, and the judgment will be made with respect to the delivery process, which is more important. According to the studied business, the source and make processes had similar values.

Table 34

Source and Make Processes for Delivery Process

	Source	Make
Source	1	1
Make	1	1

Before going deeper with the analysis, a few terminologies and analyzing tools need to be identifies and explained. There are three supermatrices associated with each network: the unweighted supermatrix, the weighted supermatrix, and the limit supermatrix (Saaty, 2003).

3.7.1. Unweighted supermatrix. The unweighted supermatrix contains the local priorities and ranking of elements derived from the pairwise comparisons throughout the network. In other words, all the local priority figures of the nodes can be obtained directly from the unweighted supermatrix. A component in a supermatrix is the block defined by a cluster name on the left and a cluster name at the top. Table 35 shows all local priorities of the nodes. However, these priorities do not provide the whole picture; they only give an idea about the pairwise comparisons and the local rankings, without taking into the consideration the effects of other nodes and clusters. To make this information more reliable, one needs to multiply the cluster values or weight by the priorities obtained from the unweighted supermatrix.

3.7.2. Cluster matrix. If all the clusters are equally significant, then it is not mandatory to make cluster comparisons, and the cluster values are set to *1/n* in the cluster matrix. Nevertheless, the clusters in a network may not be equally important. Therefore, it is required to create weights for clusters in the clusters matrix. The cluster matrix in Table 36 shows the weight of each and every compared cluster. For example, the weighted value of product types and market demand clusters are 0.143 (14.3%) and 0.857 (85.7%), respectively.

3.7.3. Weighted supermatrix. The weighted supermatrix is the matrix that results from the multiplication of the cluster matrix and the unweighted supermatrix. The weighted supermatrix for the ANP model is shown in Table 37. In actual life problems, it is important that one distinguishes the importance of the groups or clusters to which the elements belong because the final ranking and priorities of elements, with respect to the overall goal, depend on that. In the weighted matrix, we got 44% and 13% for high market and functional products, respectively. These percentages represent the global priority or the ranking of these nodes with respect to the overall goal.

3.7.4. Limit supermatrix. The limit supermatrix is achieved by raising the weighted supermatrix to powers by multiplying it by itself. When the column of numbers is the same for every column, the limit matrix has been reached, and the matrix multiplication process is stopped. The limit supermatrix for the ANP model is shown in Table 38.

From the limit supermatrix, we got weights of 0.11 for high market demand, 0.25 for functional product, 0.082 for quality and lead time of suppliers, 0.083 for make process, and 0.12 for the reliability and responsiveness of the processes.

Table 35

Unweighted Supermatrix, Local Priority of each Node in the Model

		goal	mk dmnd			Product Type		Supplier criteria			Supply Chain Processes				ply Chain Strategic Attrib		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
mk dmnd	Average	0.359	0.000	0.000	0.000	0.000	0.000	0.236	0.182	0.333	0.000	0.000	0.000	0.000	0.223	0.333	0.223
	High	0.517	0.000	0.000	0.000	0.000	0.000	0.682	0.091	0.333	0.000	0.000	0.000	0.000	0.070	0.333	0.707
	Low	0.124	0.000	0.000	0.000	0.000	0.000	0.082	0.727	0.333	0.000	0.000	0.000	0.000	0.707	0.333	0.070
Product Type	Customized	0.111	0.500	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.500	0.800
	Functional	0.889	0.500	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.857	0.500	0.200
Supplier criteria	Leadtime	0.000	0.413	0.444	0.111	0.444	0.067	0.000	0.000	0.000	0.444	0.000	0.000	0.000	0.000	0.500	0.667
	Price	0.000	0.260	0.111	0.444	0.111	0.489	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.800	0.000	0.000
	Quality	0.000	0.327	0.444	0.444	0.444	0.444	0.000	0.000	0.000	0.444	0.000	0.000	0.000	0.200	0.500	0.333
Supply Chain Processes	1.SOURCE	0.000	0.218	0.158	0.308	0.114	0.283	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.310	0.182	0.182
	2.MAKE	0.000	0.419	0.498	0.308	0.368	0.333	0.000	0.000	0.000	0.000	0.000	0.800	0.000	0.375	0.577	0.577
	3.DELIVER	0.000	0.308	0.289	0.308	0.453	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.264	0.201	0.201
	4.RETURN	0.000	0.054	0.055	0.077	0.065	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.040	0.040
Supply Chain Strategic Attributes	CO	0.000	0.413	0.073	0.691	0.089	0.600	0.000	0.000	0.000	0.072	0.077	0.077	0.493	0.000	0.500	0.200
	RL	0.000	0.327	0.256	0.218	0.323	0.300	0.000	0.000	0.000	0.301	0.462	0.462	0.311	0.800	0.000	0.800
	RS	0.000	0.260	0.671	0.091	0.588	0.100	0.000	0.000	0.000	0.626	0.462	0.462	0.196	0.200	0.500	0.000

Table 36

Cluster Matrix Obtained Using Super Decisions Software

	Goal	Market Demand	Product Type	Supplier Criteria	Supply Chain Processes	Supply Chain Strategic Attributes
Goal	0.000	0.000	0.000	0.000	0.000	0.000
Market demand	0.857	0.000	0.000	1.000	0.000	0.174
Product Type	0.143	0.076	0.000	0.000	0.000	0.111
Supplier criteria	0.000	0.257	0.333	0.000	0.413	0.329
Supply Chain Processes	0.000	0.302	0.333	0.000	0.260	0.178
Supply Chain Strategic Attributes	0.000	0.365	0.333	0.000	0.327	0.209

Table 37

Weighted Supermatrix

		goal	mk dmnd			Product Type		Supplier criteria			Supply Chain Processes				ply Chain Strategic Attrib		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
mk dmnd	Average	0.307	0.000	0.000	0.000	0.000	0.000	0.236	0.182	0.333	0.000	0.000	0.000	0.000	0.039	0.058	0.039
	High	0.443	0.000	0.000	0.000	0.000	0.000	0.682	0.091	0.333	0.000	0.000	0.000	0.000	0.012	0.058	0.123
	Low	0.107	0.000	0.000	0.000	0.000	0.000	0.082	0.727	0.333	0.000	0.000	0.000	0.000	0.123	0.058	0.012
Product Type	Customized	0.016	0.038	0.060	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.055	0.088
	Functional	0.127	0.038	0.015	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.055	0.022
Supplier criteria	Leadtime	0.000	0.106	0.114	0.029	0.148	0.022	0.000	0.000	0.000	0.248	0.000	0.000	0.000	0.000	0.165	0.219
	Price	0.000	0.067	0.029	0.114	0.037	0.163	0.000	0.000	0.000	0.062	0.000	0.000	0.000	0.263	0.000	0.000
	Quality	0.000	0.084	0.114	0.114	0.148	0.148	0.000	0.000	0.000	0.248	0.000	0.000	0.000	0.066	0.165	0.110
Supply Chain Processes	1.SOURCE	0.000	0.066	0.048	0.093	0.038	0.094	0.000	0.000	0.000	0.000	0.000	0.088	0.000	0.055	0.032	0.032
	2.MAKE	0.000	0.127	0.150	0.093	0.123	0.111	0.000	0.000	0.000	0.000	0.000	0.354	0.000	0.067	0.102	0.102
	3.DELIVER	0.000	0.093	0.087	0.093	0.151	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.036	0.036
	4.RETURN	0.000	0.016	0.017	0.023	0.022	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.007	0.007
Supply Chain Strategic Attributes	CO	0.000	0.151	0.027	0.252	0.030	0.200	0.000	0.000	0.000	0.032	0.077	0.043	0.493	0.000	0.104	0.042
	RL	0.000	0.120	0.094	0.080	0.108	0.100	0.000	0.000	0.000	0.133	0.462	0.257	0.311	0.167	0.000	0.167
	RS	0.000	0.095	0.245	0.033	0.196	0.033	0.000	0.000	0.000	0.277	0.462	0.257	0.196	0.042	0.104	0.000

Table 38

Limit Supermatrix

		goal	mk dmnd			Product Type		Supplier criteria			Supply Chain Processes				Supply Chain Strategic Attributes		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
mk dmnd	Average	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
	High	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
	Low	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Product Type	Customized	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
	Functional	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Supplier criteria	Leadtime	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
	Price	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
	Quality	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Supply Chain Processes	1.SOURCE	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
	2.MAKE	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
	3.DELIVER	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
	4.RETURN	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Supply Chain Strategic Attributes	CO	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
	RL	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
	RS	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119

3.8 Sensitivity Analysis

The overall priorities and ranking of all criteria based on judgments are shown in the limit supermatrix table, Table 38. The results show that the judgments and decisions placed high priority on high market demand and for functional products. Keep in mind that under high demand, the business fully utilizes production line capacities, warehouses, delivery scheduling, and operations in order to meet demands and not to miss any orders when possible. In this regard, the business' focus on responsiveness is more important that total cost. However, current markets are more unstable, rapidly change, and are affected by many different factors. Due to the instability of markets and customer needs and demands, businesses try to catch up and chase these demands by conducting adjustments and making alterations in the pricing, marketing, production, and engineering of products. However, what works for large companies may not work for smaller ones. Because of the massive availability and accessibility of data that exists in large companies, they act earlier than the smaller ones, which gives them advantages over smaller enterprises.

As mentioned in the characteristics of small enterprises section, SMEs tend to act like firefighters. This strategy may not work for all types of businesses, products, or markets. Actually, the limited resources that exist in small enterprises weaken them when facing external changing conditions. While the large businesses can utilize and reallocate their resources (i.e., financial resources and non-financial resources, such as production facilities, warehouses locations, marketing forces, and tools), small enterprises usually fall into undesirable situations with supply and production, on one hand, and with customer and market needs, on the other hand.

Although many researchers have found that the characteristics of small enterprises do not aid in doing better jobs, and they are considered to be disadvantages, we believe that they can be turned into competitive advantages over larger businesses when used properly and at the right time. The proposed model, the AHP and the ANP, offers small enterprises with the right tools that they can use to monitor, check, adjust, and improve processes and performance according to supply and demand. It assesses businesses based on internal operations and on external factors as well. We have examined the model under certain conditions, such as high market demand scenarios, and for a small manufacturing enterprise. It provides the business with the most significant strategic attributes, the most significant business processes that support strategy, and the importance of supplier criteria and the product type.

Nevertheless, what if demand falls, or what if the supplier criteria and conditions become more significant? Does the business need to monitor the same attributes or pay more attention to the same processes or products that were learned from the high market demand scenario? These questions need to be answered; therefore, the model is going to be used once again to make judgments and conduct pairwise comparisons, but this time under low market demand to see if things need to be changed or not.

Once again, the company under study was been asked to conduct a pairwise comparison processes, but this time, the manufacturer was asked to examine the model outputs under a low market demand scenario. The first comparison starts with the cluster comparisons (i.e., which cluster is more important with respect to the goal, market demand, or product type). The market demand and product type clusters were equally valued, and a measure of 1 was inserted into the comparison. The other comparison compares market scenarios, and Table 39 below shows the values inserted for each scenario in relation to the others.

Table 39

Market Demand Comparison for Scenaio 2

	Low	Average	High
Low	1	2	9
Average	1/2	1	9
High	1/9	1/9	1

The evaluation and the comparison among supplier criteria are shown in Table 40 below. The question to be asked here is, with respect to low market demand, which supplier criteria is more important, lead time or price, price or quality, quality or lead time. This comparison resulted in placing high local priority for price with about 57%, and quality with about 36%.

Table 40

Pairwise Comparison for the Supplier Criteria under Low Market Demand

	Lead time	Price	Quality
Lead time	1	1/6	1/6
Price	6	1	2
Quality	6	1/2	1

Likewise, other comparison processes must be initiated with the goal of facing low market demand for the coming planning period. In terms of supply chain processes, the judgments for low market demand are shown in Table 41.

Table 41

Pairwise Comparison for the Supply Chain Processes with Respect to Low Market Demand

	Source	Make	Deliver	Return
Source	1	2	4	4
Make	1/2	1	3	4
Deliver	1/4	1/3	1	4
Return	1/4	1/4	1/4	1

The judgments with respect to low market demand within supply chain attributes are shown in Table 42.

Table 42

Pairwise Comparison for Supply Chain Attributes with Respect to Low Market Demand

	CO	RL	RS
CO	1	4	8
RL	1/4	1	5
RS	1/8	1/5	1

The entire local priorities are shown in the unweighted supermatrix in Table 43. In the unweighted supermatrix, the local priorities show that the low market demand weighs more than average and high market demand scenarios. These weights were 0.582, 0.366, and 0.051, respectively. The unweighted supermatrix also shows that all product types have the same importance. The logical explanation for this is that the manufacturer has more capacity than the demand in low market situations, which allows the production of different products to meet different orders. The cluster matrix is shown in Table 44, and the weighted supermatrix is shown in Table 45. The final weights and values of criteria are shown in Table 46.

Table 43

Unweighted Supermatrix for Market Scenario 2

		goal	Market demand			Product Type		Supplier criteria			Supply Chain Processes				Supply Chain Strategic Attributes		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Market demand	Average	0.367	0.000	0.000	0.000	0.000	0.000	0.333	0.125	0.333	0.000	0.000	0.000	0.000	0.181	0.333	0.208
	High	0.051	0.000	0.000	0.000	0.000	0.000	0.333	0.079	0.333	0.000	0.000	0.000	0.000	0.065	0.333	0.661
	Low	0.582	0.000	0.000	0.000	0.000	0.000	0.333	0.796	0.333	0.000	0.000	0.000	0.000	0.754	0.333	0.131
Product Type	Customized	0.857	0.500	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.500	0.800
	Functional	0.143	0.500	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.857	0.500	0.200
Supplier criteria	Leadtime	0.000	0.333	0.333	0.075	0.333	0.078	0.000	0.000	0.000	0.075	0.000	0.000	0.000	0.000	0.500	0.667
	Price	0.000	0.333	0.333	0.567	0.333	0.487	0.000	0.000	0.000	0.696	0.000	0.000	0.000	0.889	0.000	0.000
	Quality	0.000	0.333	0.333	0.357	0.333	0.435	0.000	0.000	0.000	0.229	0.000	0.000	0.000	0.111	0.500	0.333
Supply Chain Processes	1.SOURCE	0.000	0.218	0.250	0.468	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.578	0.182	0.182
	2.MAKE	0.000	0.419	0.250	0.305	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.800	0.000	0.222	0.577	0.577
	3.DELIVER	0.000	0.308	0.250	0.156	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.158	0.201	0.201
	4.RETURN	0.000	0.054	0.250	0.072	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.040	0.040
Supply Chain Strategic Attributes	CO	0.000	0.413	0.333	0.699	0.691	0.333	0.000	0.000	0.000	0.588	0.077	0.077	0.493	0.000	0.500	0.200
	RL	0.000	0.327	0.333	0.237	0.160	0.333	0.000	0.000	0.000	0.323	0.462	0.462	0.311	0.800	0.000	0.800
	RS	0.000	0.260	0.333	0.064	0.149	0.333	0.000	0.000	0.000	0.089	0.462	0.462	0.196	0.200	0.500	0.000

Table 44

Cluster Matrix for Market Scenario 2

	goal	mk dmnd	Product Type	Supplier criteria	Supply Chain Processe	Supply Chain Strategic Attributes
goal	0	0	0	0	0	0
mk dmnd	0.5	0	0	1	0	0.174
Product Type	0.5	0.27	0	0	0	0.111
Supplier criteria	0	0.154	0.333	0	0.413	0.329
Supply Chain Processes	0	0.237	0.333	0	0.26	0.178
Supply Chain Strategic Attributes	0	0.338	0.333	0	0.327	0.209

Table 45

Weighted Supermatrix for Market Scenario 2

		goal	Market demand			Product Type		Supplier criteria			Supply Chain Processes				Supply Chain Strategic Attributes		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Market demand	Average	0.183	0.000	0.000	0.000	0.000	0.000	0.333	0.125	0.333	0.000	0.000	0.000	0.000	0.032	0.058	0.036
	High	0.026	0.000	0.000	0.000	0.000	0.000	0.333	0.079	0.333	0.000	0.000	0.000	0.000	0.011	0.058	0.115
	Low	0.291	0.000	0.000	0.000	0.000	0.000	0.333	0.796	0.333	0.000	0.000	0.000	0.000	0.131	0.058	0.023
Product Type	Customized	0.429	0.135	0.135	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.055	0.088
	Functional	0.071	0.135	0.135	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.055	0.022
Supplier criteria	Leadtime	0.000	0.051	0.051	0.012	0.111	0.026	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.165	0.219
	Price	0.000	0.051	0.051	0.088	0.111	0.162	0.000	0.000	0.000	0.388	0.000	0.000	0.000	0.293	0.000	0.000
	Quality	0.000	0.051	0.051	0.055	0.111	0.145	0.000	0.000	0.000	0.128	0.000	0.000	0.000	0.037	0.165	0.110
Supply Chain Processes	1.SOURCE	0.000	0.052	0.059	0.111	0.083	0.083	0.000	0.000	0.000	0.000	0.000	0.088	0.000	0.103	0.032	0.032
	2.MAKE	0.000	0.099	0.059	0.072	0.083	0.083	0.000	0.000	0.000	0.000	0.000	0.354	0.000	0.039	0.102	0.102
	3.DELIVER	0.000	0.073	0.059	0.037	0.083	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.036	0.036
	4.RETURN	0.000	0.013	0.059	0.017	0.083	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.007
Supply Chain Strategic Attributes	CO	0.000	0.139	0.113	0.236	0.230	0.111	0.000	0.000	0.000	0.260	0.077	0.043	0.493	0.000	0.104	0.042
	RL	0.000	0.111	0.113	0.080	0.053	0.111	0.000	0.000	0.000	0.143	0.462	0.257	0.311	0.167	0.000	0.167
	RS	0.000	0.088	0.113	0.022	0.050	0.111	0.000	0.000	0.000	0.039	0.462	0.257	0.196	0.042	0.104	0.000

Table 46

Limit Supermatrix for Market Scenario 2

		goal	Market demand			Product Type		Supplier criteria			Supply Chain Processes				Supply Chain Strategic Attributes		
		GOAL	Average	High	Low	Customized	Functional	Leadtime	Price	Quality	1.SOURCE	2.MAKE	3.DELIVER	4.RETURN	CO	RL	RS
goal	GOAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Market demand	Average	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
	High	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Low	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Product Type	Customized	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
	Functional	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
Supplier criteria	Leadtime	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
	Price	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
	Quality	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Supply Chain Processes	1.SOURCE	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
	2.MAKE	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	3.DELIVER	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
	4.RETURN	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Supply Chain Strategic Attributes	CO	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
	RL	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
	RS	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081

In regular circumstances, when functional products are in demand, the cost factor is considered as the most significant factor in a competitive market, but when facing high demand, the manufacturing strategy changes. This is the main reason for, and one of the benefits gained from, connecting market demand scenarios, strategic attributes, and product types in the model. The results show that supplier lead time plays a crucial role in improving performance and achieving business goals. If the manufacture has more than one supplier, this means that during the low seasons, the manufacturer might look for suppliers with low cost and good quality at the expense of lead time. Table 47 and figure 41 below compare and show the differences in weighted values of criteria (i.e., product type, market demand, supply chain strategy, strategic attributes, and supplier criteria).

Table 47

Ranking of Critera at Various Market Scenarios

		Market Scenario	
		Low	High
Product Type	Customized	0.048	0.029
	Functional	0.051	0.025
Supplier Criteria	Lead time	0.053	0.082
	Price	0.080	0.043
	Quality	0.063	0.082
Supply Chain Processes	1.SOURCE	0.049	0.036
	2.MAKE	0.062	0.083
	3.DELIVER	0.031	0.043
	4.RETURN	0.017	0.008
Supply Chain Strategic Attributes	CO	0.104	0.071
	RL	0.111	0.119
	RS	0.081	0.119

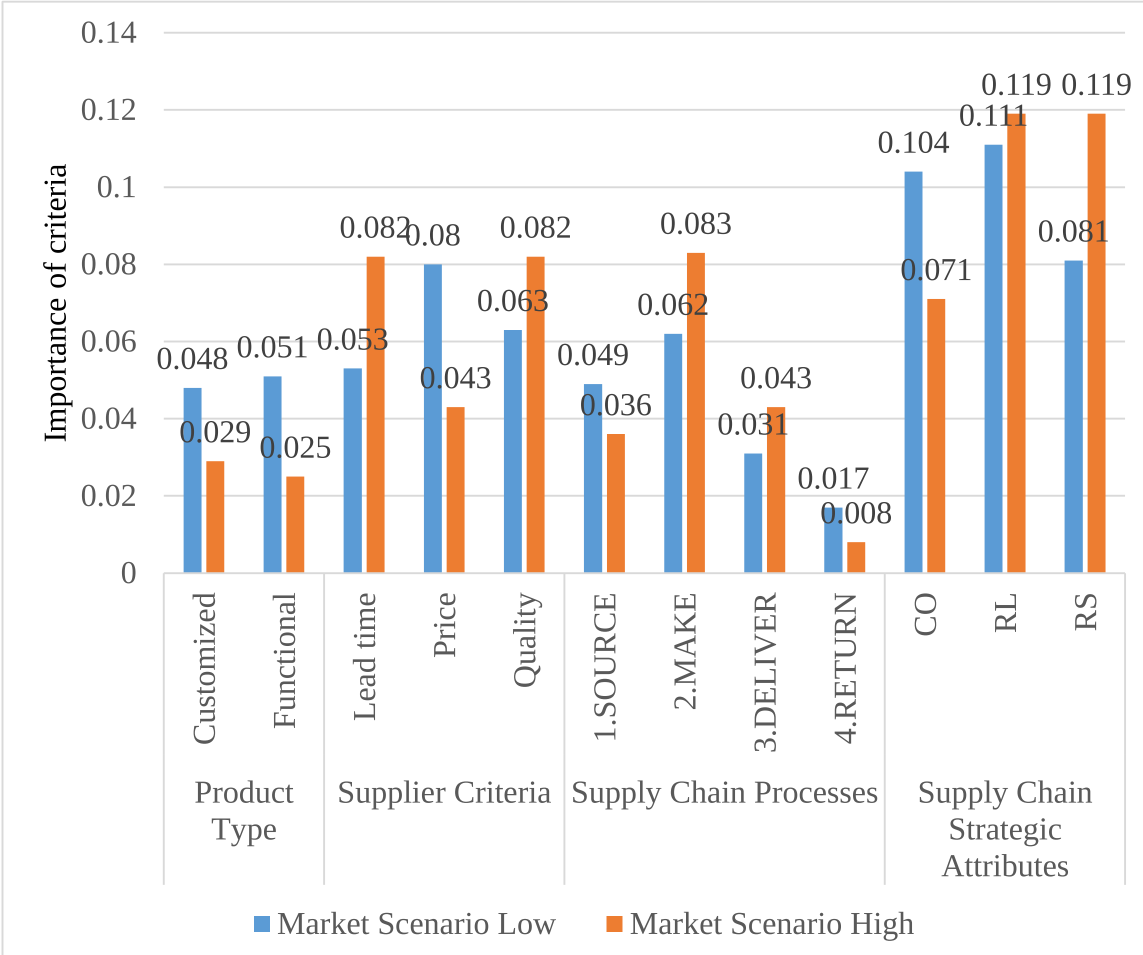


Figure 41. Ranking of Critera at Various Market Scenarios.

3.9 Calculating Supply Chain Overall Performance (SCOPI)

As of late, organizational performance and measurements have received much consideration from specialists and professionals. The role of these measures and measurements in the accomplishment of an organization cannot be exaggerated because they influence strategic and operational arranging and control. Therefore, performance measurements have an essential part to play in setting goals, assessing performance, and deciding future approaches. Within the context of supply chain strategic attributes in small enterprises, we have identified three major attributes, which are cost, reliability, and responsiveness. Take reliability and cost, for example; when the ability to perform tasks decreases due to operational factors, such as frequent machine shutdowns, defective products, reprocessing, or a high rejection rate, then the cost of operations and response times are increased as well. Consequently, the saved cost will be decreased due to the extra work and time that is required to produce the same quantities. When reliability of operations is high, however, it highly contributes to improving the response rate and to reducing costs as well.

The importance of each attribute depends on the enterprise’s strategy and capabilities, as shown in the implementation of the AHP and ANP models through the case study. In the following sections, the three attributes will be identified and formulas to calculate each one will be introduced.

3.9.1. Cost. The cost attributes describe the cost of operating the process. Typical costs include labour or manpower cost, material cost, transportation cost, and indirect costs. In the traditional manufacturing context, however, the cost will be the cost of raw materials and overhead costs. The final price of the product is revealed, after adding cost, in the following mathematical formula:

$$\text{Price} = \text{Cost} + \text{Profit} \tag{3.12}$$

This allows decision-makers to know how much they need to charge customers for their product or service, but what if the competitor has better prices for the same service or product? How can a small or medium firm compete with this? There is only one way and, that is to reduce the cost of manufacturing that product or providing that service. In this case, the above formula will be rewritten as follows:

$$\text{Profit} = \text{Price} - \text{Cost} \tag{3.13}$$

This implies that the benefit will be specifically subject to the assembling expense of the item. In the event that a business needs higher benefits, they will need to decrease the expense of assembling. Yet, by what means can a producer diminish the expense of assembling without influencing the quality, lead time, or agreeability norms? This is where lean manufacturing techniques will be convenient.

Lean manufacturing is concerned with taking out wastes. In lean manufacturing, wastes are characterized as the exercises or procedures that do not increase the value of the final product or service. On the off chance that one disposes of the wastes from a system, they will clearly be lessening the expense of assembling. Aside from that, lean manufacturing will take out wasted time, decreasing lead times. Quality improvement is another advantage of lean manufacturing. This means that a lean manufacturer will be able to deliver high quality products to the market with lower lead times and at lower costs than their competitors, while making greater profits. The cost structure based on the presented models can be broken down to the followings:

- Cost to Source: This includes costs that are incurred due to material acquisition (e.g., costs to order and receive items, costs to schedule deliveries of items, costs to transfer items, and storage costs).

- Cost to Make: This includes all costs that are associated with transforming raw materials into final products. The cost to make a product includes direct materials, direct labour, machinery costs, and indirect product-related costs.
- Cost to Deliver: This is the sum of costs associated with delivery and installation of final products. The cost to deliver includes distribution, transportation, inventory, ordering, customer service, field repair, etc.
- Cost to Return: This category of cost includes products that are returned by customers, defective products, the cost of wrongful deliveries and materials that are returned to suppliers.

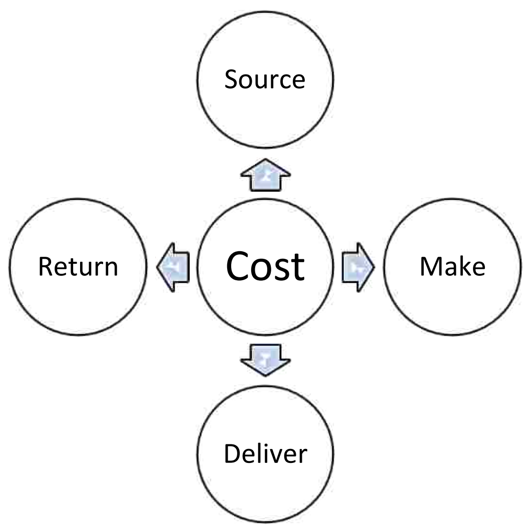


Figure 42. Costs associated with supply chain processes.

The total supply chain costs equal the sum of costs associated with the source, make, delivery, and return processes, which can be expressed as follows:

$$\text{TSCC} = \Sigma C11 + C12 + C13 + C14 \tag{3.14}$$

Because the cost calculations will be based on lean profit formulas, the focus will be on the cost savings ratio. The overall cost saving equation follows:

Actual expenses per (order/planned period) - *Estimated expenses (order/planned period)*

Therefore, the cost saving ratio (X1) can be calculated based on the percentage of orders that do not exceeded the estimated cost, or the percentage of the overall savings from the estimated expenses.

3.9.2. Reliability. The reliability attributes address the capability of performing tasks and activities as anticipated. Reliability emphases the predictability of the result of a process. Reliability can be measured by the correct items delivered at the right locations. The order fulfilment rate indicates the percentage of orders meeting delivery performance standards with complete and accurate documents and with no delivery damage.

For many applications, reliability problems usually will not cause tragic failures, so they may not appear critical and may be overlooked. Although they may seem to be very insignificant, many reliability problems do cause customers to be displeased.

The reliability of supply chain process can significantly affect the next process. For example, when a manufacturer receives a wrong batch, quantity, or quality, the make process will be affected, and the inventory level, delivery schedule, quality or quantity, and ultimately, customer satisfaction will be harmed.

The reliability of products and processes also disturb responsiveness. When supply chain processes suffer from low reliability, the response time to customer orders and cost will be increased, which in turn, increases customer complaints and causes the loss of customers and markets. Leachman et al., (2005) suggested that the removal of non-value time is a critical element in improving manufacturing performance and that improved performance arises from both cost savings and quality improvement. The overall order fulfillment rate (X2) can be calculated using the total number of orders as follows:

$$X2 = ((\text{total orders} - \text{error orders}) / \text{total orders}) * 100 \quad (3.15)$$

3.9.3. Responsiveness. Commonly, organizations measure their performance against criteria like utilization, profitability, or request finishing date and think they are doing fine in the event that they get high scores; however an organization can exceed expectations according to these criteria and still lose to a competitor on the off chance that it cannot get its item to the client when guaranteed. The responsiveness attribute defines the speed at which tasks and activities are performed.

There are several metrics used in measuring the responsiveness of operations, such as calculating the order fulfillment cycle time. The customer order promised cycle time is the anticipated or agreed upon cycle time of a purchase order. It is the gap between the purchase order creation date and the requested delivery date. However, this tells only the expected cycle time and not the actual cycle time. The customer order actual cycle time, however, is the average time it takes to actually fill a customer's purchase order. This measure can be viewed on an order or an order line level.

The measure begins when the client's request is sent, gotten, or entered to the system. The measure closes at either the season of shipment or at the season of conveyance to the client. Based on that, this actual cycle time should be compared to the agreed cycle time. For example, if the actual cycle time is equal to or less than promised, then the response rate is high and vice versa. As cited in several publications, the customer order cycle time can be calculated using the following equation:

$$\textit{Actual delivery date} - \textit{purchase order creation date} \tag{3.16}$$

The promised customer order cycle time can be calculated as follows:

$$\textit{Requested delivery date} - \textit{purchase order creation date} \tag{3.17}$$

The overall response rate can be measured using the following equation:

$$\text{Response rate (X3)} = \text{(R1/R2)*100} \tag{3.18}$$

In order to evaluate the overall supply chain performance of a small enterprise based on the three attributes, a simple formula was established that takes into consideration the preferences of each and every individual business and operations environment. As was mentioned earlier, every business weighs each attribute differently, and sometimes the same business places different weights depending on changes in the business environment. The supply chain overall performance index can be calculated as follows:

$$SCOPI = w1*x1+w2*x2+w3*x3 \tag{3.19}$$

Recall the small manufacturer studied. The analysis showed that the manufacturer focused on responsiveness and reliability as the major attributes of the strategy when facing high market demand. Based on the limit supermatrix, the reliability and responsiveness achieved were about 39% each, in relation to the total weight assigned for the strategic attributes, and the cost savings ratio was about 22%. Assume that the manufacturer had achieved 70%, 60%, and 80% in cost saving ratio, reliability, and responsiveness, respectively. In such a case, the overall supply chain score of the manufacture would be 70%. Table 48 and figure 43 below show the performance of each strategic direction or attribute and its contribution to the overall performance.

When implementing any new procedure, it is usually best to start small and expand from a base of success. The most important issue here is to pick a process where employees are engaged and motivated—ideally an area where employees are interested in learning new things and applying ideas towards improvement. The improvement process for the manufacture, for example, may start with increasing the reliability of processes because they have high value but achieve low performance. As a matter of fact, increasing the reliability of processes significantly contributes to the improvement of responsiveness and reduces the cost of manufacturing.

Table 48

SCOPI for Market Scenario 1, High Market Demand

	Weight in %	Actual in %	Performance in %
CSR	22%	70%	15.4%
RL	39%	60%	23.4%
RS	39%	80%	31.2%
SCOPI			70.0%

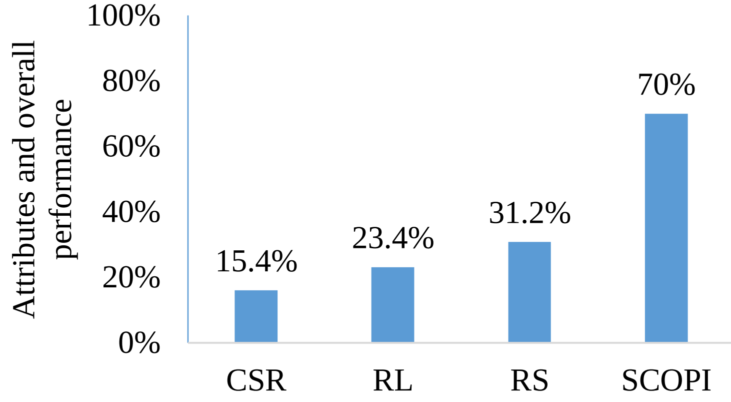


Figure 43. SCOPI for market scenario 1, high market demand.

The SCOPI card below shows the current performance readings and the new goal to achieve. The strategic attributes, such as cost, reliability, and responsiveness, must be linked to the success drives or business processes in order to identify business weaknesses and to allocate resources in order to improve performance and achieve the ultimate goals. Table 49 shows performance improvement card with current and future targets.

Table 49

Calculation of Overall Supply Chain Performance

SCOPI						
Current Performance Index						
CSR %	RL%	RS%	SCOPI%			
15.4	23.4	31.2	70%			
New Objectives						
CSR		RL		RS		SCOPI%
Weight%	Actual%	Weight%	Actual%	Weight%	Actual%	

CHAPTER 4

DISCUSSION AND CONCLUSIONS

4.1 Discussion

The market competition and globalization, in addition to the limitations that are found in small manufacturing enterprises, require tighter business and operations control measures. These factors pressure small and medium-sized enterprises to make better strategic and operational decisions in order to achieve competitiveness with their rivals.

Exclusive focus on financial measures, however, does not completely assist in achieving long term success. The absence of objective and formal strategic decisions and the inappropriate implementation of performance measurement systems in small enterprises increases the chance of failure. Therefore, we aimed to develop a model that assists in translating informal and qualitative decisions in small enterprises into quantitative decisions that allows for the evaluation and measurement of decisions and actions, consequently increasing the chances for success. Implementing multi-criteria decision methodology (MCDM) allows for the integration and linking of various levels of decision-making processes, the conversion of subjective decisions into objective ones, the use of individual business preferences, and the ranking of strategic attributes and business processes.

The first model in this research, the AHP model, was created as a fast track for small businesses that run simple operations and need to evaluate their subjective judgments and track the effects of those judgments on their strategies, business priorities, and operations. The model also provides a clear view of the linkages and connections among strategic and operational levels in a hierarchical structure. The flexibility of the model can be observed in two ways. First, it provides flexibility to various businesses to run the performance model based on their own preferences or judgments. Secondly, the model can be used by a business based on different market scenarios, without the need to change the structure. The proposed analytical hierarchy processes (AHP) model effectively integrates internal processes and strategic attributes while considering external market demand scenarios as well. The implementation of the AHP model was conducted on a small manufacturing enterprise that mainly produces functional types of products that are used in construction and buildings. The results showed that, based on the manufacturer's judgments, the enterprise needs to pay more attention to the cost and reliability of sourcing and to the making processes during low market demand, while in high market demand, the manufacturer prefers to focus on the reliability and responsiveness of the make and delivery processes.

Notice that the small manufacturing enterprise decided to meet various market scenarios with different strategies. In low market demand, the business is willing to cut costs and reduce expenses by reducing the cost of materials, for example. As mentioned previously, the cost of materials in this industry represents more than 70% of the total cost; hence, nothing was better than starting with the sourcing process. In other words, the manufacturer needs to carefully select suppliers who can provide the required raw materials at low prices even if they sacrifice responsiveness. Recall Fisher's model, which states that an efficient supply chain is more appropriate for functional products; the results obtained from the AHP model agreed with Fisher's model to some degree. However, when market demand is high, the role is changed, especially for manufacturers who run businesses in highly competitive markets.

Many small businesses work in complicated environments that require more integrated and comprehensive models. In a hierarchical model, such as the developed AHP model, criteria are connected by arrows going in one direction from top to bottom. These types of connections do not offer reciprocal interactions among nodes and clusters, and they do not allow for internal dependencies of the criteria within a cluster. Therefore, another model using an analytical network processes (ANP) approach was developed. Unlike the AHP approach, the ANP approach allows for the evaluation and assessment of the effects and sensitivities of the interactions among the model's elements. The analytic network process (ANP) allows one to capture all kinds of interactions and make accurate predictions to improve decision-making processes. In the proposed ANP model, the manufacturer's relation to suppliers was considered and the significance of suppliers to business operations and strategic attributes were established. A new loop connection, which links the processes together, was formed. Another loop connection linking interdependencies among strategic attributes is also an important aspect of the proposed ANP model.

Although the implementation of the ANP model required a little more discussion with the manufacturer to understand the connections and links among criteria and clusters than the former model, the results of the ANP model outputs were more precise in terms of the judgments and the decision made by the manufacturer. The proposed ANP model arrived, however, at similar results as the AHP model for the same manufacturer. Finally, a mathematical equation was generated to assess businesses in measuring their overall performance based on the results obtained from the proposed model. Therefore, the ultimate goal of the proposed models to accurately evaluate overall performance score was achieved.

In addition to the described applications of the models as performance improvement and assessment tools, other benefits can be obtained. The models provide businesses with more focus on market needs and links them to internal resources. They also help in the planning of future actions which may reduce uncertainties that occur due to the changes in supply and demand. They also help in sharing information and future plans among suppliers, manufacturers, and markets. The models also help small enterprises in organizing and focusing on core processes and utilizing resources in order to achieve competitive advantages.

4.2 Limitations

The models are analytical instruments that clarify what strategic attributes need to be emphasized and measured as well as how to measure them. The models also assess the overall supply chain performance of a small business. The proposed models, however, are not a guarantee of an enterprise' success, especially when implemented without understanding and realizing the involved processes, the types of products, and the surrounding market and competition. The proposed performance improvement and measuring models are expected to significantly increase the chances of success and improve an enterprise's performance in relation to internal and external environments by providing systematic approaches.

Regarding the proposed models, it is neither possible nor required to measure everything within an enterprise. The strategic attributes that were chosen to be measured in the models are attributes that were commonly used and selected by researchers in previous studies conducted on small enterprises. Given this limitation, the models proposed in this research do not involve all types of business attributes, only the major ones.

It is also important to highlight the fact that the models and performance equations were implemented in the context of single, small family-owned manufacturing enterprise. Although the results obtained from the models support the directions of the previous academic research and practices of business, implementing the models in only one small manufacturer could be insufficient to prove their generality. Therefore, it is important to confirm the practical implementation of the models on other small enterprises. Due time constraints, we could not wait for the actual implementation of the measurements in that studied small enterprise. As a matter of fact, the implementation and debugging of such model could take a long time, and involves many co-dependent and interacting processes.

Another limitation of the models is that, the judgments are based on particular behaviour of markets. In other words, if the decisions for particular market scenarios do not represent or do not reflect the actual demands, all other decisions made based on the models may not be accurate or lead to focusing on the wrong processes or measures. Moreover, expected limitations in general include inappropriate judgments on criteria, inappropriate setting of targets and standards for performance measures, improper implementation, or incorrect interpretation of the results, which could lead to wrong actions and undesired results.

4.3 Future Work

Further research on the use and the implementation of the proposed models in different enterprises is required. Extended efforts may be needed to investigate and develop a performance model that incorporates other supply chain strategic attributes, manufacturing attributes, and other performance indicators as well. It would also be appropriate to conduct new research on how to incorporate quality management and manufacturing concepts and requirements, such as, for example, total quality management, ISO standards, and lean six sigma, into one of the analytical models for small and medium sized enterprises.

4.4 The Novelty and Research Contributions

This research contributes to and enriches the area of designing and applying enterprise performance measurement from two perspectives, academic and practice. The novelty of this model can be summarized as follows: it is the first and unique kind of research that considers, investigates, and employs major internal and external supply chain factors and elements within the context of small enterprises. It is the pioneering research that provides small businesses with a mathematical formula that assesses its overall supply chain.

The major contribution of the research is to provide small, mainly manufacturing, enterprises with analytical models which measures performance in an integrated, flexible, and comprehensive manner. The methodology effectively integrated significant criteria in a unified model that is capable of mapping small enterprises' strategic decision-making processes. The model is linked to the strategic planning and decision-making of the enterprise. More precisely, the research contribution can be summarized in the following themes:

- A methodology that transform subjective and informal information into a form suitable for quantitative and formal decision making.
- A model that connects supplier's criteria to strategic attributes, business operations, and market demands as demonstrated in the ANP model
- A model for measuring the overall performance of small enterprises that integrates strategic management processes and decision-making methods
- A method that can be used to calculate the overall supply chain performance of small enterprises.

Table 50

Previous Performance Measurement Models Versus the Proposed Model

	OPM	IPM	BSC	AHP Model	ANP Model
Strategy alignment	○	x	●	●	●
Strategy improvement	x	x	●	●	●
Developed to measure overall performance	x	x	x	●	●
Flexibility	x	●	x	●	●
Balance	●	●	●	●	●
Process oriented	●	●	○	○	●
Clarity and simplicity	○	●	x	●	●
Causal relationships	x	●	●	x	●
Depth	●	○	●	○	●
Breath	●	x	●	○	●

(Adopted: Garengo et al.:2005)
Note. ○ = partially satisfies the requirement; x = not included; ● = fully satisfies the requirement
OPM: Organizational performance model, IPM: Integrated performance model, BSC: Balance Scorecard.

The proposed ANP model fully achieves the requirements of the strategic and comprehensive performance measurement system which, thus, can be utilized as a device to influence business accomplishment by enhancing performance and maintaining competitive advantages. Reports revealed that about 50% of survived SMEs effectively keep up their competitive advantage and different reports attributed the achievement in keeping up the upper hand to the act of using a strategic performance measurement system. Reports additionally revealed a large portion of SMEs failures are credited to industry experience, business planning, system of control, and management competency. Although the significance of the models and approach utilized as a part of this study have not been statistically demonstrated, the essentialness of the proposed models can be explained in the following:

1. Increase industry experience: Linking the internal resources of a business to its external needs helps in utilizing resources and organizing overall business structure accordingly.
2. Improve business planning: The proposed models assist in identifying the strengths and weaknesses of a business. The models help identify mission, cost structure, customers, markets, and other external influences. About nine out of ten business failures in the United States are caused by a lack of general business management skills and planning.
3. Improve systems of control: measures help owners manage organizational activities. Small enterprise have no control on the external factors influencing its environment, such as customers, suppliers and competitors. However, small business can adapt its internal activities to meet and reduce external challenges.

4. Improve management competency: The proposed models assist management in implementing and monitoring the strategic, tactical, and operational plans of a business.
5. Establish workable goals: The proposed models help small businesses in understanding and identifying weaknesses, improvement opportunities, and setting realistic goals.

4.5 Conferences and Papers Publications

1. *Winter Simulation Conference 2013*. Washington, DC.

Alomar, M., & Pasek, Z. (2013). Improving performance of SME's using SCOR and AHP methodology. *Winter Simulation Conference*. Available at http://informs-sim.org/wsc13papers/includes/files/360.pdf

2. *International Conference of Operation Research and Enterprises Systems 2014*. France.

Alomar, M. and Pasek, Z. (2014). A supply chain strategy management model for small and medium sized enterprises. In *International Conference of Operation Research and Enterprises Systems* (pp.46-56). SCITEPRESS.

3. *The 47th CIRP CMS 2014 Conference*. Windsor, Canada.

Alomar, M. and Pasek, Z. (2014). Linking supply chain strategy and processes to performance improvement. Available at http://www.sciencedirect.com/science/article/pii/S2212827114004235

4. *International Symposium on the Analytic Hierarchy Process 2014*. Washington, DC.

Alomar, M. and Pasek, Z. (2014). Improving performance of SME's using supply chain framework and multi-criteria decision methodology. *International Symposium of the Analytic Hierarchy Process*. Available at http://www.isahp.org/uploads/p743878.pdf

5. Pinson, E., Valente, F., Vitoriano, B. (2015). *Operations Research and Enterprise Systems*: *Third International Conference, ICORES 2014*, Angers, France, March 6-8, 2014, Revised Selected Papers. Published by Springer-Verlag.

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APPENDIX

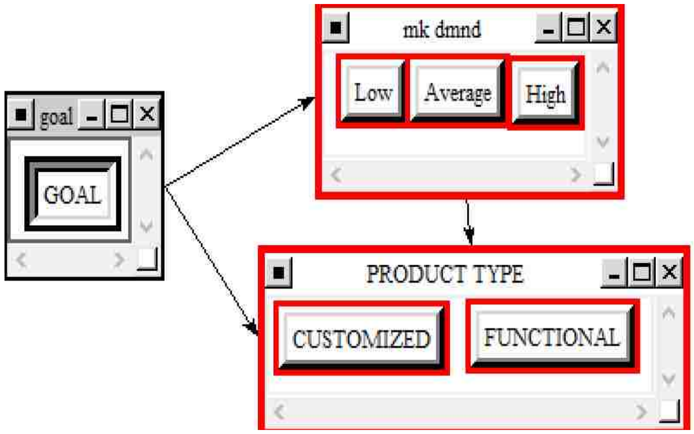

Figure A.1. Market demand and product type clusters using Super Decisions software.

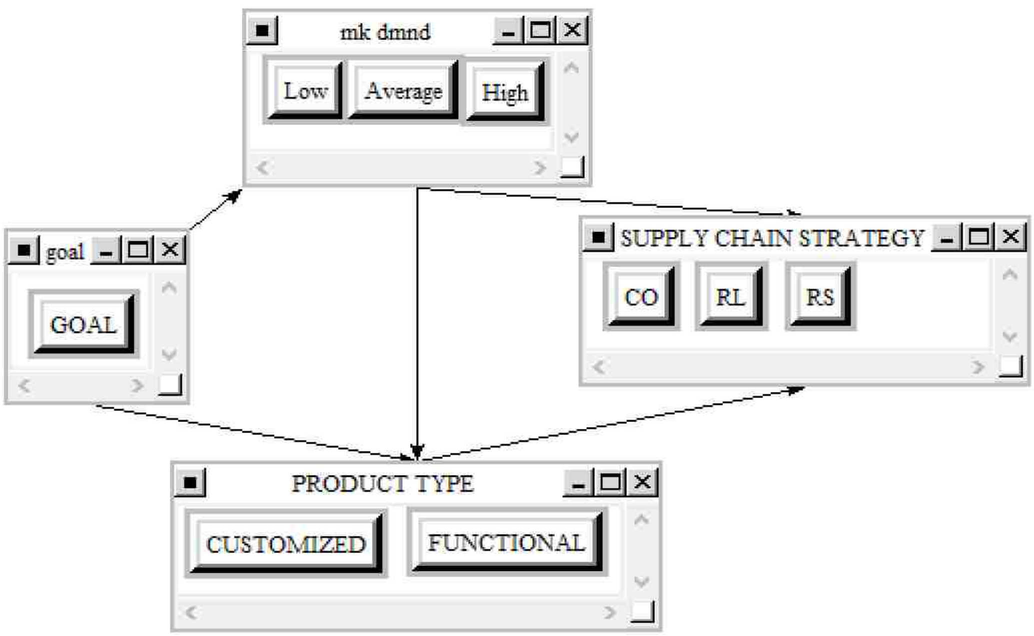

Figure A.2. Connections among supply chain strategic attributes, market demand, and product type.

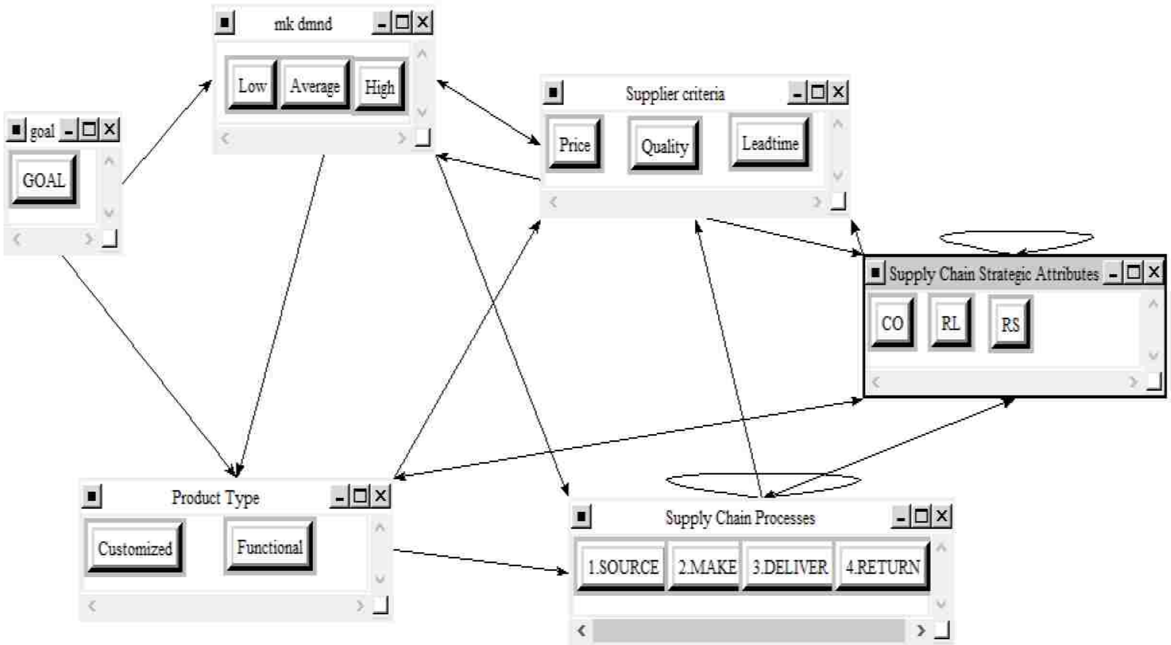

Figure A.3. The completed ANP model using Super Decisions software.

Figure A.4. Screenshot of pairwise comparison of market demand scenarios using Super Decisions software.

Figure A.5. Screenshot of cluster comparison, market demand and product type using super decisions.

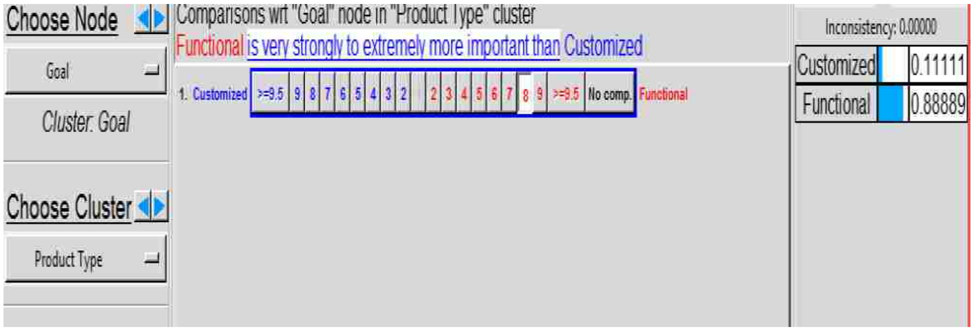

Figure A.6. Screenshot of product type comparison process using super decisions.

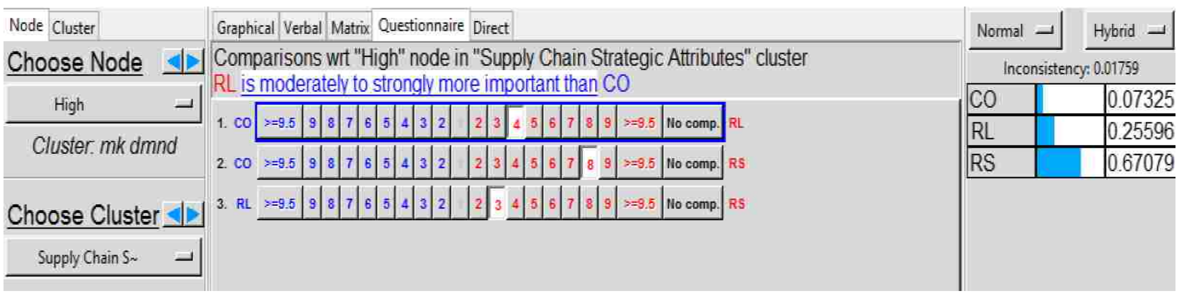

Figure A.7. Screenshot for the pairwise comparison among the strategic attributes with respect to high demand using Super Decisions software.

Figure A.8. Screenshot for the pairwise comparison among the strategic attributes with respect to fucntioanl prodcut using Super Decisions software.

Figure A.9. Comparison processes among supplier criteria using Super Decisions software.

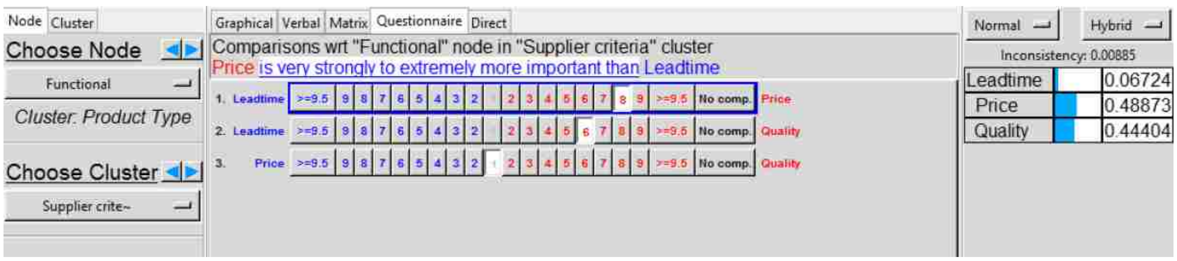

Figure A.10. Screenshot of supplier criteria comparison and local priorities with respect to functional product using Super Decisions software.

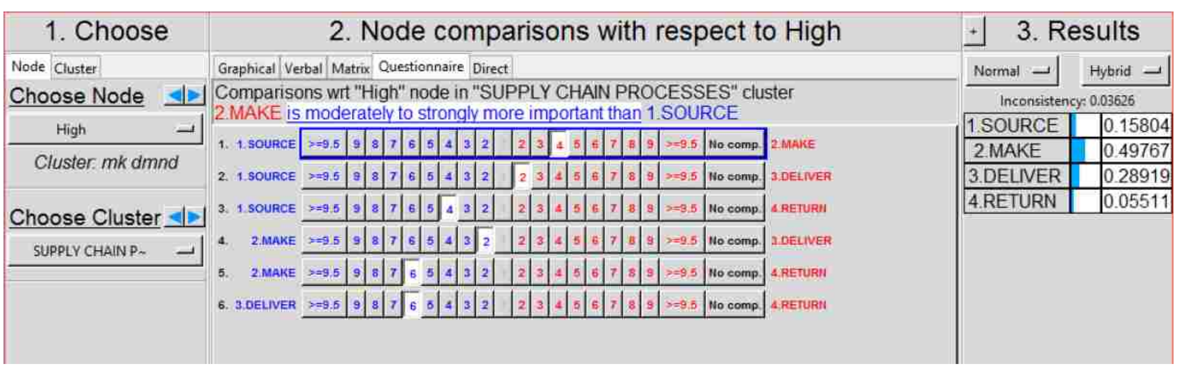

Figure A.11. Screenshot of the pairwise comparison process inserted for the processes with respect to the high market demand using Super Decisions software.

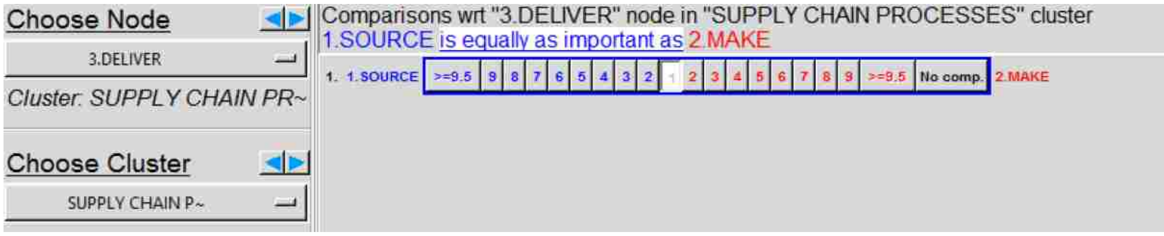

Figure A.12. Screenshot of the loop comparison among supply chain processes using Super Decisions software.

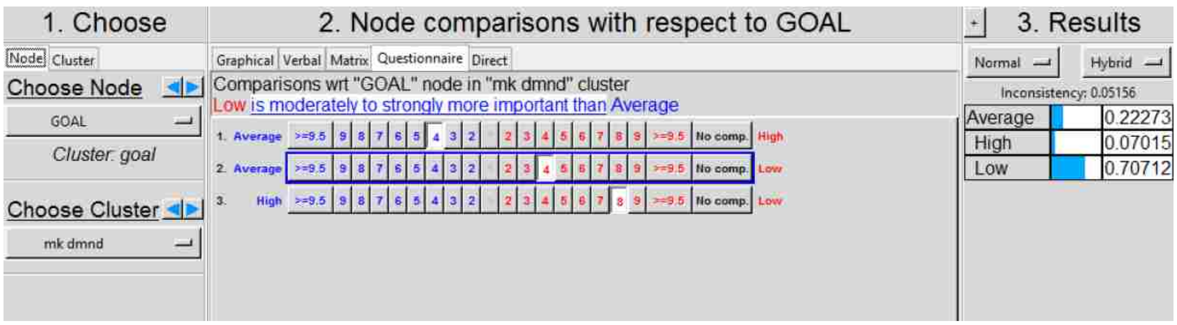

Figure A.13. Screenshot of the market demand using Super Decisions software.

VITA AUCTORIS

Madani Alomar was born in 1975 in Gizan, Kingdom of Saudi Arabia. He graduated from high school in 1994. From there, he went on to study at the King Abdul-Aziz University, where he obtained a B.Sc. in Industrial Engineering in 1999, and a M.Sc. in Industrial Engineering in 2005. In 2009, he attended the Odette School of Business at the University of Windsor and obtained a Master of Management degree in 2010. He is currently a candidate for a PhD in Industrial and Manufacturing Systems Engineering at the University of Windsor and hopes to graduate in spring 2015. Madani Alomar has about ten years of experience in the manufacturing industry, particularly in small and medium-sized manufacturing enterprises. He has worked as a marketing specialist, a quality control assistant manager, and an assistant production manager.